ANNUAL REPORT TO CONGRESS—
FISCAL YEAR 2000

FROM THE
STRATEGIC ENVIRONMENTAL RESEARCH
AND DEVELOPMENT PROGRAM

March 2001

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EXECUTIVE SUMMARY

The Strategic Environmental Research and Development Program (SERDP) is the Department of Defense's corporate environmental science and technology program. To fulfill its mission to address environmental problems through innovative research and share that information across Federal and private organizations, SERDP executes the program in partnership with the Department of Energy and the Environmental Protection Agency. Further, SERDP fully leverages complementary programs within the Department of Defense and solicits interest from other public and private research organizations.

The organization and management of SERDP is described in Section I. As directed by the SERDP Council, the Executive Director and Program Office Staff implement the Program with the support of various working groups and panels to meet high priority, DoD mission-related environmental needs. The activities, achievements, and recommendations of the SERDP Council, Scientific Advisory Board, and Executive Director are detailed in this section.

SERDP conducts basic research through advanced technology development in the following four Technology Thrust Areas: Cleanup (including unexploded ordnance), Compliance, Conservation, and Pollution Prevention. Section II describes significant accomplishments achieved during FY 2000 within each of the Thrust Areas. Highlights of these accomplishments include: (1) new technologies capable of detecting unexploded ordnance (UXO) with high detection rates to significantly reduce the cost of DoD site characterization and cleanup; (2) new technologies to remediate and/or contain groundwater contaminated with explosives and ammonium perchlorate; (3) advances to achieve the long-term sustainability of DoD testing and training ranges, including adaptive management of ecosystems and techniques to assess the potential release of energetics pollutants; and (4) the development of less toxic energetic compounds and munitions and a non-hazardous chemical agent resistant coating (CARC) for military hardware. Each of these advancements will ensure DoD maintains mission-readiness while complying with high priority and emerging environmental requirements.

In each fiscal year cycle, SERDP must manage ongoing research within the program, solicit and select new research projects, and plan future research initiatives and funding distribution for each Thrust Area. Section III provides an overview of the SERDP Program, including the goals, environmental and operational research drivers, actual and planned funding levels, and the planned research initiatives for each Thrust Area. In FY 2000, the SERDP budget was $58.50 million for the funding and management of 111 research projects. The budget request for FY 2001 of $51.54 million is planned for the funding and management of 110 projects, including both continuing and new start projects. Summaries of each project funded in FY 2000 and those planned for funding in FY 2001 are provided in the four Thrust Areas in Appendices A through D. Research topic areas for which proposals will be requested for projects funded in FY 2002 are provided in Appendix E.

This report provides a summary of SERDP's activities and its most significant accomplishments for FY 2000, its plans for FY 2001, and new research activities to be addressed in FY 2002. It responds directly to the requirements as stated in Title 10, U.S.C. section 2902, as modified. This report complies with FY 2001 amendment to the SERDP statute that repeals the requirement for an Annual Report from the SERDP Scientific Advisory Board, and includes the contents of that report in this Annual Report to Congress.

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I. PROGRAM MANAGEMENT

Background

Authorizing Legislation

In June of 1990, Senator Sam Nunn addressed the Senate to advise his colleagues about the seriousness of the environmental problems faced by this nation, and specifically by the Department of Defense (DoD) and the Department of Energy (DOE). Having recently been relieved of the strenuous efforts and financial burden of the Cold War, it became apparent to Senator Nunn and others that a significant capability existed both in the nation's Federal research infrastructure, as well as the defense industry whose technical skills could be brought to bear on this Nation's environmental matters of concern. From this revelation, he recommended the creation of a Strategic Environmental Research Program, composed of several Agencies and Departments, that would seek to apply defense technologies for environmental benefits.

Later that year, Congress established the Strategic Environmental Research and Development Program (SERDP) in Public Law 101-510 (Title 10, U.S.C., §§2901-2904) funded by DoD and planned and executed in partnership with DOE and the Environmental Protection Agency (EPA). The immediate success of the Program lead to SERDP becoming the DoD's corporate environmental Science and Technology (S&T) program. SERDP fully leverages complementary programs found within the Army, Navy, and Air Force, and those of the DOE and the EPA, and over the past decade, measures have been implemented to take full advantage of the intrinsic capabilities of the participating organizations. This feature makes SERDP unique as it can tap the vast technical resources of the Federal research infrastructure to meet the needs of our most pressing environmental matters of concern. During the past five years, SERDP has successfully engaged in directly funding the private sector and academia in a step that further widens the spectrum of technological capability and innovation.

This report provides a summary of SERDP's activities and most significant accomplishments during fiscal year 2000, its plans for fiscal year 2001, and new research initiatives to be addressed in fiscal year 2002. It responds directly to the requirements as stated and modified in Title 10, U.S.C. §2902. This report complies with the fiscal year 2001 amendment to the SERDP statute that repeals the requirement for an Annual Report from the Scientific Advisory Board (SAB), but includes the actions of the Board in the Annual Report of the SERDP Council to Congress.

Mission

The purposes or mission of SERDP can be found in the statute. The clear intent of Congress was to not only address environmental problems through research efforts, but also to share information across and within Federal and private lines in order to more rapidly and effectively deal with these serious problems. Specifically, the four purposes of SERDP are to:

SERDP addresses DoD and congruent DOE environmental matters of concern through cooperative research.

- Address environmental matters of concern to the DoD and the DOE through support for basic and applied research and development of technologies that can enhance the capabilities of the Departments to meet their environmental obligations;
- Identify research, technologies, and other information developed by the DoD and the DOE for national defense purposes that would be useful to governmental and private organizations involved in the development of energy technologies and of technologies to address environmental restoration, waste minimization, hazardous waste substitution, and

other environmental concerns and to share such research, technologies, and other information with such governmental and private organizations;

- Furnish other governmental organizations and private organizations with data, enhanced data collection capabilities, and enhanced analytical capabilities for use by such organizations in the conduct of environmental research; and

- Identify technologies developed by the private sector that are useful for DoD and DOE defense activities concerning environmental restoration, hazardous and solid waste minimization and prevention, and hazardous material substitution and provide for the use of such technologies in the conduct of such activities.

This mission, crafted over 10 years ago, remains highly relevant, and while significant successes have been achieved, a number of difficult technical challenges remain.

Requirements

SERDP is a "requirements-driven" program that directly responds to defense requirements generated by the Services and sanctioned by the Deputy Under Secretary of Defense for Environmental Security (DUSD/ES). It is critical that the limited funds available for environmental technology R&D be focused on the highest priority requirements of the Services. Each Service develops prioritized user requirements through internal processes that include members of the technology user community. These requirements are collected, cross-leveled, and correlated at the DoD level by the DUSD(ES) through the Environmental Security Technology Requirements Group (ESTRG). The ESTRG is composed of the officials responsible for the Environmental Security programs within the Services and representatives of the R&D community.

Requirements submitted to the ESTRG are validated and ranked into high, medium, and low categories based on the priorities assigned by the Services. They form the basis of the Defense Technology Objectives (DTO) for environmental technology programs of the Services, SERDP, and the Environmental Security Technology Certification Program (ESTCP). The environmental technology DTOs are merged with other DTOs for other defense technology requirements within the DoD to form the overarching Defense Technology Area Plan (DTAP). The DTOs and the DTAP are developed jointly by the Services and DDR&E through the Reliance Process and form the basis for all DoD Science and Technology initiatives.

DoD environmental concerns may be divided into two broad categories of concerns:

- Those that impact training, logistics, and combat operations, and
- Those that have cost and performance impacts on the supporting infrastructure.

Both categories can negatively impact the Department's ability to perform its primary mission of maintaining military readiness for national defense.

In the course of addressing DoD's highest priority environmental needs in the areas of Cleanup, Compliance, Conservation, and Pollution Prevention, SERDP also has sought opportunities to help solve other significant national and international environmental problems through the application of DoD's technical capabilities, analytical systems, and information.

The SERDP Management Structure

SERDP is a multi-agency managed program funded by the Department of Defense. Pursuant to Title 10, U.S.C., SERDP receives general oversight and policy guidance from the SERDP Council which is composed of members from the DoD, DOE, and EPA. Also included in this authorizing language is a requirement for an Executive Director to lead the day to day Program activities, and a Scientific Advisory Board (SAB) that is charged with providing advice and recommendations to the SERDP Council on projects/proposals reviewed. Further, the SAB may advise the Council regarding other programmatic, funding, or technically related issues with respect to the Program. Other activities shown in Figure I-1 represent those that were established by the Council and Executive Director to support Program needs.

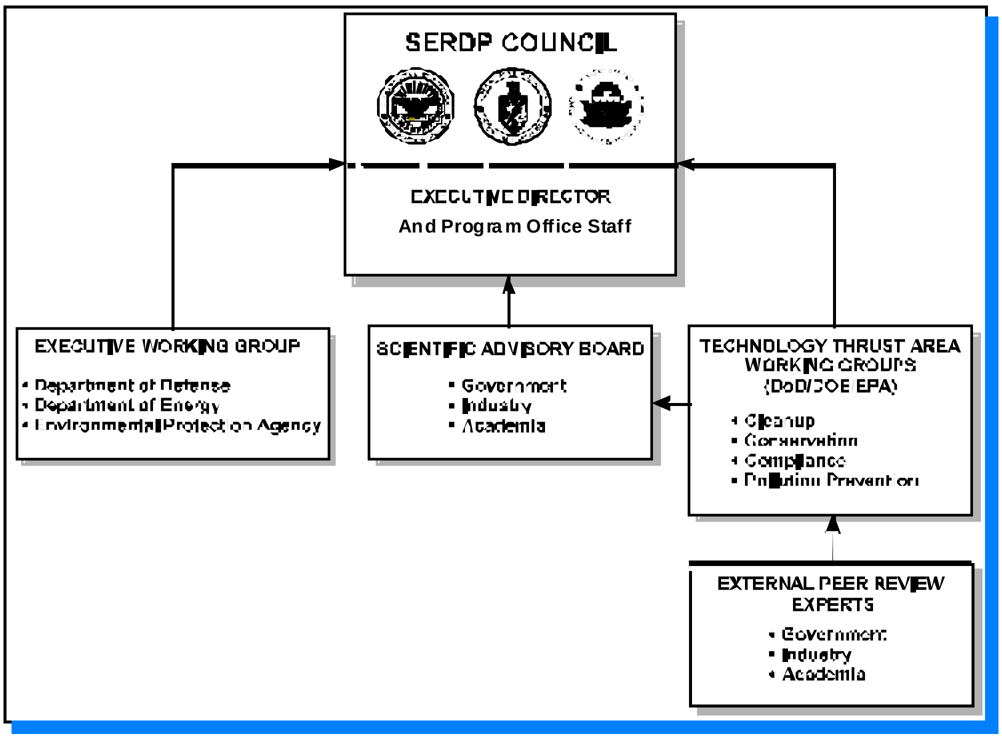


Figure I-1. SERDP Organization.

SERDP Council

Title 10, U.S.C. §2902 established the Strategic Environmental Research and Development Program Council to oversee management of SERDP. Specifically, this Council prescribes policies and procedures to implement the Program and may enter into contracts, grants, and other agreements in accordance with other applicable law to carry out the purposes of SERDP. Congress intended the Council to be a multi-agency membership body to promote maximum exchange of information and to minimize duplication of environmentally related research, development, and demonstration activities through close coordination with the military departments and Defense agencies; the Department of Energy; the Environmental Protection Agency; the National Oceanic and Atmospheric Administration; the National Aeronautics and Space Administration; other departments and agencies of the Federal, State, and local governments; and other organizations engaged in environmentally related research.

Established by law, SERDP's multi-agency Council ensures integrated, non-duplicative research.

DoD and DOE Council representatives alternate as Co-chairs.

Consistent with the SERDP statute and with facilitating multi-agency cooperation, the Secretary of Defense has designated the Deputy Under Secretary of Defense for Science and Technology (DUSD/S&T) as chairperson for each odd-numbered fiscal year, and the Secretary of Energy has designated the Director of the Office of Science to serve as chair for each even-numbered year. Other members are assigned per guidance provided in the SERDP statute. The following are the Council members who served during a portion of, or for the entire, FY 2000.

Council Members - FY 2000

Dr. Martha Krebs, Dr. James Decker,
and Dr. Mildred Dresselhaus (Chair)
Department of Energy
Office of Science

Dr. Delores Etter
Department of Defense
Science and Technology

Colonel Rick Drawbaugh
and Colonel Brian McCarty
Department of the Air Force
Environment, Safety, and Occupational Health Technologies

Brigadier General Thomas Gioconda
and Ms. Madelyn Creedon
Department of Energy
Defense Programs

Ms. Sherri Goodman
Department of Defense
Environmental Security

Captain Michael Grimes and
Captain Jim Evans
U.S. Coast Guard
Research and Development

Dr. Carolyn Huntoon
Department of Energy
Environmental Management

Ms. Catherine Kominos
and Dr. Thomas Killion
Department of the Army
Research and Laboratory Management

Dr. Norine Noonan
Environmental Protection Agency
Research and Development

General Joseph Ralston
and General Richard Myers
Department of Defense
Joint Chiefs of Staff

Dr. Fred Saalfeld
Department of the Navy
Naval Research

Mr. Bradley Smith *(non-voting member)*
Executive Director
Strategic Environmental Research and Development Program

A list of current SERDP Council members may be found on the SERDP website (www.serdp.org).

Executive Working Group

The Executive Working Group (EWG) is an extension of the Council and serves as a working-level representation of the Council. This body, while not directed by law, facilitates SERDP policy preparation, investment strategy considerations, and annual program plan development. Members of the EWG may be found on the SERDP website (www.serdp.org).

SERDP Scientific Advisory Board

SAB members focus on technical quality.

Established in accordance with the SERDP statute, the SERDP Scientific Advisory Board (SAB) assures that the Program maintains clear focus on technical quality. The SAB has the authority to make recommendations to the

Council regarding technologies, research, projects, programs, activities, and, if appropriate, funding within the scope of the SERDP. The SAB is composed of no more than 14 members who are jointly appointed by the Secretary of Defense and the Secretary of Energy in consultation with the Administrator of the Environmental Protection Agency. During FY 2000, SAB membership remained consistent.

To ensure that SERDP objectives are congruent with the Administration's goals, two members of the SAB are mandated in the statute - the Science Advisor to the President, or his/her designee, and the Administrator of the National Oceanic and Atmospheric Administration, or his/her designee. Similarly, to ensure that regional and global environmental issues are appropriately addressed in SERDP, at least one member should represent the interests of State governments and one member should represent environmental public interest groups. The list below reflects SAB membership in FY 2000.

Scientific Advisory Board Members - FY 2000

Dr. Braden Allenby
AT&T

Dr. Patrick R. Atkins
Aluminum Company of America

Dr. Mary Barber
The Ecological Society of America

Dr. Rosina M. Bierbaum
Office of the Science Advisor to the President

Dr. Steven Clifford
National Oceanic and Atmospheric Administration

Dr. Kenneth Dickson
University of North Texas

Dr. Raymond C. Loehr
University of Texas at Austin

Dr. Perry L. McCarty
Stanford University

Dr. Jean'ne M. Shreeve (Vice Chair)
University of Idaho

Dr. C. Herb Ward (Chair)
Rice University

Mr. Randolph Wood
Texas Natural Resources Conservation Commission

Dr. Lily Young
Rutgers University

The statute directs the SAB to review all projects with a value in excess of $1,000,000. Several years ago, the SERDP Council modified this direction by requesting that each new start effort and every continuing project exceeding $900,000 be reviewed by the SAB. During FY 2000, each project meeting this criteria was reviewed to ensure technical quality and fiscal responsibility. Furthermore, the SAB confirmed that multiple projects responding to the same or a similar requirement were complementary in approach and well coordinated.

Executive Director and Program Office Staff

Title 10, U.S.C. authorizes an Executive Director to direct and focus the day-to-day efforts of SERDP. Mr. Bradley P. Smith retained the position of Executive Director at the pleasure of the Secretary of Defense. The Executive Director is a non-voting member of the SERDP Council and a voting member of the EWG. After collocating with the ESTCP in 1999, Dr. Jeffrey Marqusee, the ESTCP Director, was selected to also serve as the SERDP Technical Director. This collocation and sharing of responsibilities has served to broaden the staff's technical skills and facilitate technology transition from one program to another. The balance of the Federal staff consisted of three technical Program Managers and a Financial Officer who have been detailed from the military Services' R&D infrastructure. These individuals include:

- Ms. Catherine Vogel - Cleanup Program Manager for technologies
- Mr. Charles Pellerin - Pollution Prevention Program Manager for technologies
- Dr. Robert Holst - Compliance and Conservation Program Manager for technologies
- Ms. Brenda Batch - Financial Officer

Technology Thrust Area Working Groups

As evidenced by the small size of Program Office staff, the breadth of technical knowledge demanded by SERDP far exceeds the limited staff in the SERDP Program Office. Consequently, SERDP must rely on the technical skills offered by the participating Services and Agencies to assist in the technical aspects of program development, program monitoring, and technology transfer. For each of the Technology Thrust Areas (Cleanup, Compliance, Conservation, and Pollution Prevention), a Technology Thrust Area Working Group (TTAWG) was established to help solicit and review technical proposals, formulate and recommend the annual program plan, conduct technical reviews of the ongoing projects, and facilitate technology transfer according to the needs of their users in the field. TTAWGs offer several advantages over conventional R&D management schemes. First, their members are selected by the Services and Agencies as represented on the Council. Second, they bring both a wealth of understanding of the needs of their organization, but also knowledge of similar completed or ongoing efforts. This knowledge helps SERDP to completely avoid duplication of effort and promote joint and cooperative funding of projects. TTAWG members, for the most part, provide their services as a collateral assignment, however, without their assistance, SERDP would have difficulty achieving the same level of success. Current membership on the TTAWGs may be found on the SERDP website (www.serdp.org).

Peer Review Experts

Assisting the TTAWGs and the Program Office in their quest to select quality research proposals are the Peer Review Experts. Following the model established by the National Science Foundation, SERDP proposals must undergo an independent Peer Review prior to receipt of initial funding. The results, scores, and evaluation comments of this review are passed directly to the TTAWGs who use this information to develop their recommended list of new start projects. Further, these same results are passed to the Scientific Advisory Board for consideration during their proposal review and deliberations.

Peer Reviewers come from all walks of disciplinary life - from industry, academia, and government as well. Each reviewer is certified to be without conflict of interest, an expert in their field and profession, and credible on record. Peer Reviewers are identified and tasked under a support contract, and in FY 2000, 77 Peer Review Experts were used to evaluate 161 proposals.

SERDP Strategy

Program Goals

The SERDP Council ensures that the partnership focuses on the mission needs of the DoD and empowers the EWG with developing goals and an investment strategy that will assist SERDP to successfully satisfy these mission needs. In 1993, the EWG assembled to develop the SERDP Strategic Guidance that served as a framework within which to develop the annual SERDP program plan. This Strategic Guidance continues to provide the overarching guidelines to Program Managers and participants in the Program. Included in this document are the SERDP goals which are to:

- Resolve environmental concerns in ways that enhance military operations, improve military systems effectiveness, and help ensure the safety of personnel; and

- Support technology and process development that reduce operational and life cycle costs, including those associated with environmental cleanup and costs of full compliance with environmental laws and regulations.

SERDP's goals address the highest priority environmental needs of the DoD and those congruent needs of the DOE.

SERDP achieves its goals by promoting cooperative environmental technology development and a strong effort in information dissemination. Specifically, SERDP succeeds by:

- Identifying and supporting programs of basic and applied research and development to:
  - Accelerate cost-effective cleanup of contaminated defense sites.
  - Facilitate full compliance with environmental laws and regulations at reduced cost.
  - Enhance training, testing, and operational readiness through prudent land management and conservation measures.
  - Reduce or eliminate defense industrial and operational waste streams through aggressive pollution prevention programs that strongly encourage use of non-hazardous, non-toxic, non-polluting, and other environmentally sound materials, substances, and processes.

- Promoting the effective exchange of information regarding environmentally related research and development activities.

SERDP promotes cooperative environmental technology development and information transfer.

- Ensuring that SERDP research and development (R&D) activities complement, but do not duplicate, Tri-Service R&D programs and other ongoing activities.

- Providing appropriate access to data under the control of, or otherwise available to, the Departments of Defense and Energy that is relevant to environmental matters.

- Facilitating the transfer of unclassified DoD and DOE environmental information and technology to other sectors of society that might be able to use them to advance national environmental objectives.

- Emphasizing multi-service, inter-departmental research and development projects and using the unique capabilities of the partnering Federal agencies, private industry, and academia to solve the Departments' environmental problems.

Key Metrics for SERDP Success

1. Address the highest-priority, defense mission-relevant environmental requirements with emphasis on multi-service issues.

The following four key metrics are used to maintain Program quality and enhance the success of the Program:

The Executive Director and his staff worked hand-in-hand with ODUSD(ES) to establish clear lines of communication, address effectively the Department's highest priority environmental requirements, and foster transition of technical efforts to field demonstration or implementation. Based upon the successful solicitations of the past few years, SERDP continued to solicit proposals from the non-Federal sector. Through the use of focused Statements of Need, the

Executive Director solicited cooperatively funded and executed projects to address high-priority multi-service needs. The TTAWGs facilitated this process by communicating effectively and applying their knowledge of the needs and capabilities of the Federal R&D infrastructure.

SERDP often holds workshops to explore the state-of-science, technology gaps, and opportunities for research in needs area as where it may be difficult to interpret this need. From these workshops, several key Statements of Need can be identified. In FY 2000, a workshop was held on the subject of Cultural Resources Management.

2. Pursue/achieve universal, world-class technical excellence.

World-class research is considered the cornerstone of SERDP projects. SERDP continued to use external Peer Review Experts in addition to the comprehensive multi-agency review procedures to ensure that technically sound proposals performed by world-class researchers are selected for funding. Technical experts representing universities, industry, and government participate in the Peer Review process. Additionally, the SAB, TTAWGs, and the Program Office staff all emphasize the need for each research team to demonstrate superior technical merit and perform according to world-class research standards.

3. Emphasize and promote technology transfer.

Transfer of technology, from research to the DoD environmental user community, is one of the key objectives of SERDP. This objective is achieved by supporting applied research and technology demonstrations that respond directly to high-priority, DoD mission-related, environmental needs. With FY 2000 marking its ninth year of technology development, SERDP is aggressively pursuing technology transfer mechanisms. The recent co-location of ESTCP with SERDP has already helped to facilitate project transitions, both between Programs and into other Agencies' certification programs as well. Many of the projects initiated in the earlier years have been, or are being completed and are now ready for field demonstration, implementation, or transition to the next step of development.

Significant focus on technology transfer has been placed on the Principal Investigators (PI) of all SERDP projects at both briefings to the SAB as well as at the In-Progress Reviews (IPR). At these IPRs, PIs are required to demonstrate their interaction with the user community or those who will sponsor further development. Members of the multi-agency TTAWGs, Joint Engineers Management Panel (JEMP) members, and key representatives from ODUSD(ES) attended the IPRs in FY00 and provided various potential technology transfer opportunities to the PIs.

4. Ensure sound fiscal management.

Timely and complete financial reporting is one of the principal keys to SERDP's success. The SERDP Executive Director has continued to ensure that the Program complies with the DoD fiscal guidance. Effective controls include periodic fiscal review of projects, implementing aggressive corrective actions to promote effective use of scarce R&D resources, and implementation of various information management/monitoring tools which fully utilize state-of-the-art Internet capabilities.

Research Framework and Technical Strategy

SERDP has the flexibility to fund basic and applied research, or advanced technology development projects as needed.

Within the Services' Environmental Quality Programs, Program Elements exist to provide funding specifically focused on either basic research, applied research, or advanced technology development. The authors of SERDP's statute understood the need to easily and judiciously allocate funds against the highest priorities and most intractable problems faced by DoD. Accordingly, SERDP has the flexibility to perform under all of these research categories. Figure I-2 illustrates SERDP's role in the DoD environmental technology development process.

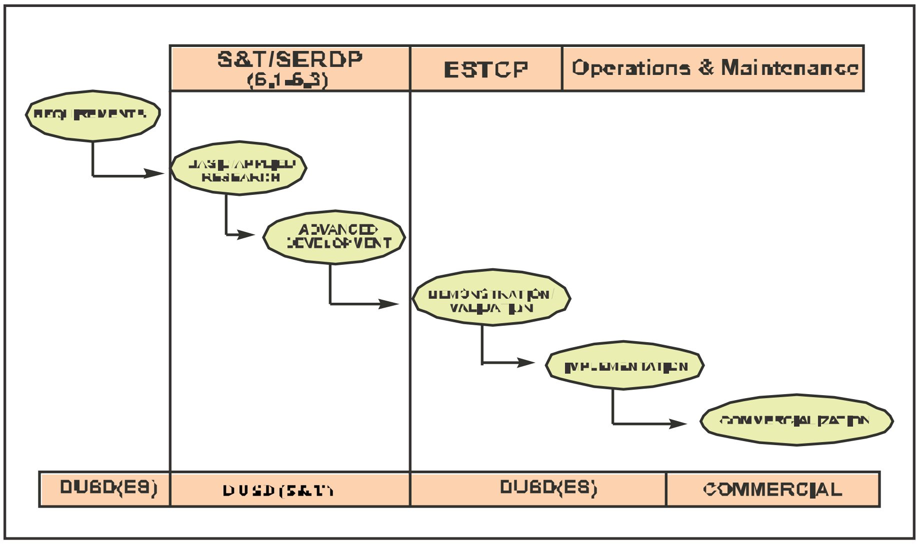


Figure I-2. Environmental Technology Development Process.

Using the multi-agency Technology Thrust Area Working Groups to formulate the annual Program plan that is based on validated service requirements, SERDP ensures that the most pressing needs and intractable environmental problems are addressed and properly funded. Each member of the TTAWG brings knowledge of their issues and programs to the table. Consequently, the resulting Program plan has been thoroughly reviewed to ensure no duplication of effort exists. More importantly, it identifies areas that might benefit from cooperative funding. This feature promotes efficient use of defense resources, effective, timely completion of complex projects, extends applications of defense information to others, and builds on existing science and technology to derive more useable and cost-effective approaches for achieving reductions in environmental risks.

Figure I-3 represents the research taxonomy that defines the SERDP Program. The primary areas of emphasis were developed in response to user community needs for science and technology required to accomplish the military mission in an environmentally compliant manner. This taxonomy follows the four pillar structure that is consistent with the focus of the Office of the Deputy Under Secretary of Defense for Environmental Security [ODUSD(ES)], that corresponds to those identified in the National Environmental Technology Strategy, and that directly parallels the four pillars of the Tri-Service Environmental Quality Technology programs. The research taxonomy reflects the current areas of emphasis under each of the four pillars.

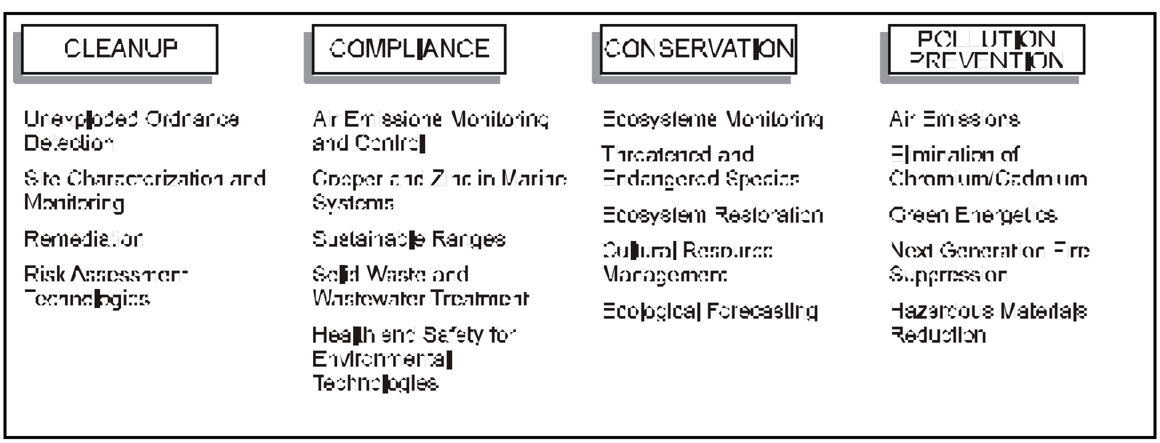


Figure I-3. SERDP Research Taxonomy.

Technical Strategy

For FY 2000, the SERDP Council directed the continuing pursuit of seven avenues in planning and executing defense mission-relevant environmental research and development:

- ✔ Identify and fund major-impact, multi-agency environmental R&D programs to solve high-priority, mission readiness related concerns of DoD;
- ✔ Identify opportunities to accelerate existing DoD environmental quality R&D programs and fund those that address the highest priority concerns of the Department;
- ✔ Identify, leverage, adapt, and/or adopt existing technologies to address environmental concerns of DoD and DOE;
- ✔ Advance and use applicable state-of-the-art modeling and simulation capabilities to accomplish SERDP goals;
- ✔ Use the technical and research capabilities of the SERDP partners, including their unique data collection and analysis capabilities, as appropriate;
- ✔ Plan for a transition of successfully proven technologies to demonstration and validation or to commercialization and implementation; and
- ✔ Encourage high-risk, high-payoff novel approaches to resolve environmental problems through the use of low-cost, short-term, exploratory R&D efforts.

Search for Innovation

With respect to the last strategic element, SERDP continues to seek innovative ideas with commensurate technical risk. The SERDP Exploratory Development Program, or SEED, that was initiated in FY 1999, has succeeded in soliciting novel ideas that were demonstrated under a low-cost ($100,000 or less), short-term (one year), proof-of-concept study. SEED projects and the larger, longer-term "Core" efforts both respond to the highest priority needs as defined in published Statements of Need (SON). These SONs are released annually with a Federal Call for Proposals and a non-Federal Broad Agency Announcement. In search of world-class research, SERDP promotes direct participation from the private sector, including small and large businesses and academic institutions. In FY 2000, two of these SEED efforts were successful in their study phase and are proposing follow-on work for FY 2001. The accomplishments of these efforts are described in Section III entitled, "Program Description" and Appendices A and D.

Investment Strategy

Each year the SERDP Council annually determines the distribution of funding to the Thrust Areas. The Council seeks the advice and recommendations of the SERDP Scientific Advisory Board and the Executive Working Group to best position SERDP to respond to both pressing needs as well as environmental problems that loom in the future. Figure I-4 depicts the percentage of Program funding trends for each technology Thrust Area from FY 2000 through FY 2005. While forecasts are based on known or expected requirements and stated goals of the Services and ODUSD(ES), actual requirements for R&D may change from year to year. Consequently, these trends may not reflect actual investments, but are developed for planning purposes.

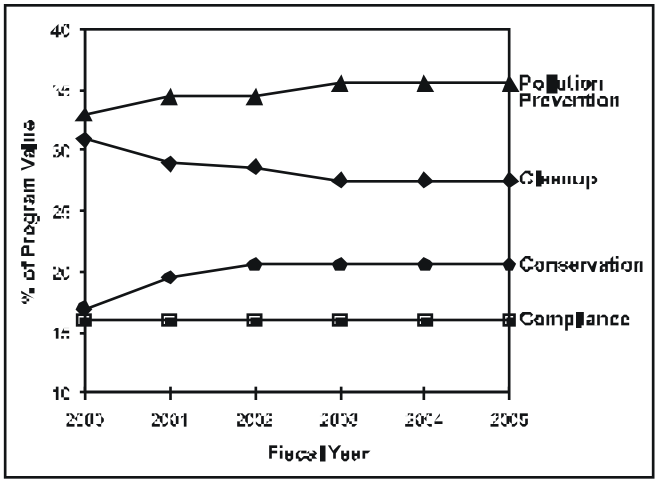


Figure I-4. Funding Balance across the SERDP Thrust Areas.

UXO detection and DNAPL detection and remediation demand adequate Cleanup R&D resources

Cleanup: Without question, the return on investment continues to be high for cleanup technology development. However, in order to affect specific future DoD cleanup goals, most technologies currently under development must be delivered to the field very soon. Accordingly, investments in cleanup generally are on a slight downward trend. There are, however, two intractable and pervasive problems faced by DoD, unexploded ordnance and dense non-aqueous phase liquids that preclude a drop in cleanup technology investment beyond FY03.

Sustainable development is fully supported by the DoD and SERDP

Pollution Prevention: Clearly the biggest returns in the future are expected by reducing or eliminating the generation of pollutants. Accordingly, an increase in Pollution Prevention technology investment is anticipated over the next three years. A focused investment to eliminate future DoD waste streams will preclude the environmental consequences experienced in the past. The DoD promotes sustainable development and SERDP is a strong proponent of its tenets. SERDP invests significantly in new processes that support sustainability and will work cooperatively and systematically to foster development and ensure national security without compromising the ability of future generations to meet their needs.

Research to assist DoD maintain compliance with current and anticipated regulations

Compliance: Current environmental regulations, such as the Marine Mammal Protection Act, Clean Air Act Amendments, and Safe Drinking Water Act may preclude, or severely restrict military training, operations, and manufacturing activities. SERDP efforts are directed at these various regulations to reduce the costs and operational limitations associated with Notices of Violations claimed against our defense facilities and operational forces. The future regulatory environment remains unclear with respect to the promulgation of new regulations or a relaxation of existing regulations. Given this uncertainty, funding for SERDP compliance-related technology development is anticipated to remain stable.

SERDP supports efforts that promote responsible resource management

Conservation: Land management issues and those regarding natural and cultural resources management continue to demand the attention of Base Commanders and their staffs, and accordingly, Conservation technologies have the greatest potential to impact readiness of military units. Research results from this area will help to avert legal accusations and resolve stalemates that have occurred due to lack of scientific evidence - evidence to support the position that military testing and training exercises and other practices do not negatively impact natural and cultural resources. Successful efforts are underway to support environmentally-sound land use management, and these efforts will ensure the sustainability of testing and training ranges. But as these generally long-term research efforts mature to demonstration, investments in Conservation efforts are anticipated to increase.

Core versus SEED: A majority (97 percent) of the SERDP investment is allocated to funding "Core" projects - those that generally require two to four years and several hundred thousand dollars to complete. SERDP's SEED investment ($1.6 million) provides SERDP an opportunity to capture truly novel ideas and develop these ideas through proof-of-concept, without having to risk significant investment. For FY 2001, $1 million is reserved for new start SEED efforts, and $0.6 million is allocated to two continuing projects that have successfully demonstrated promise of high payoff in their initial study.

Management Actions

Council

Multi-agency management and oversight of SERDP continues to be one of the clear strengths of SERDP. Active participation by the members of the SERDP Council, their designated representatives on the Executive Working Group (EWG), and participation on the Technology Thrust Area Working Groups (TTAWG) precludes duplication of effort, ensures quality Program content, and facilitates information transfer. This tri-parte arrangement, composed of executive, programmatic and technical individuals who represent the three primary participating organizations, yields a depth and breadth of knowledge and experience at several levels of management and technical expertise lending significant credibility to the Program.

Multi-Agency participation is a clear strength of the Program.

On September 23, 1999, the SERDP Council approved the FY 2000 Program Plan and the FY 2001 Investment Plan. For FY 2000, SERDP was appropriated $58.5 million that included funding for two additional specific interest projects.

The Council again met one year later on September 28, 2000 to approve the FY 2001 Program. The President's Budget Request (PBR) for FY 2001 was $51.4 million, however, Congressional support for the Program resulted in an appropriation of $59.6 million. Thirteen million dollars represented additions to the PBR to fund five Congressional interest projects, $3 million of the existing budget request was reserved for one Congressional interest project, and $4.8 million of projects were non-prejudicially cut from the Program. The Council authorized the Executive Director to manage these Congressionally added projects to ensure they were appropriately focused on defense issues.

When reviewing the FY 2002 Investment Strategy, the Council acknowledged the severity of the problems faced by the DoD in the areas of UXO detection and DNAPL detection and remediation. Accordingly, the Council modified their earlier investment plan by limiting their planned Cleanup investment reduction by half - from a two percent to a one percent reduction.

Scientific Advisory Board

In accordance with Section 2904, Title 10, U.S.C., the Scientific Advisory Board is required to meet a minimum of four times during the Fiscal Year. In FY 2000, the SAB met four times, and all four meetings were held in Arlington, VA. Consistent with the statute, the Board made recommendations to the SERDP Council through the Executive Director regarding the projects reviewed. They also assisted and advised the

Council in identifying environmental opportunities and provided advice on other environmental issues within the scope of SERDP.

Figure I-5 provides a list of dates and locations of all SAB meetings held during FY 2000. In accordance with the Federal Advisory Committee Act, all meetings were open to the public and detailed records of events are maintained. Further, all records, reports, working papers, and agendas were made available to the public for review. In FY 2000, no requests were made to review this information.

SAB Meeting No.	Dates	Location	Projects Briefed		
			Ongoing	New Starts	Total
1	October 19, 1999	Holiday Inn at Ballston Arlington, VA	11	4	15
2	March 14-15, 2000	Rosslyn Plaza North Arlington, VA	6	1	7
3	August 9-10, 2000	National Rural Electric Cooperative Association Arlington, VA	-	13	13
4	September 13-15, 2000	Holiday Inn at Ballston Arlington, VA	-	17	17

Figure I-5. Summary of FY 2000 SAB Meetings.

During FY 2000, the SAB continued to be committed to enhancing three processes within SERDP: research initiation, quality control, and technology transfer.

Commitment to Enhancing the Research Initiation Process

Consistent with the SAB's desire to define and fulfill its role within SERDP's statutory requirements, in a manner that most effectively utilizes the collective expertise and experience of the Board, the SAB reaffirmed its commitment to ensure that SERDP complies with the statute by soliciting and funding projects that are sharply focused on the environmental needs of the DoD and those congruent needs of the DOE. The Board reviewed and contributed to the process of preparing and issuing Statements of Need (SON). In the course of review, the SAB was instrumental in identifying opportunities to enhance the expected research product. Additionally, their final quality control review ensured that the SONs clearly articulated the objective of each and every need. This process was instrumental to fostering properly focused research proposals and minimizing irrelevant submissions in response to the broad solicitation.

The Board continued its proactive strategic role in identifying and defining environmental research gaps and associated technology development opportunities. The Board continued to support strongly the concept of focused technical workshops to provide an assessment of the state of the science and identify and prioritize research needs specific in areas of interest to SERDP. As a result of workshops held in the past, numerous SONs were generated that resulted in many proposals. For example, the ongoing FY 2002 solicitation includes an SON related to cultural resources management that directly corresponds to research needs articulated in a workshop held on that subject in FY 2000.

During their review and evaluation of proposals, the SAB conscientiously scrutinized each effort to understand and enhance the research partnerships that were proposed. Considered to be a major strength of the Program, cooperative research efforts have demonstrated a higher quality of effort by ensuring that each facet of the project is afforded a second look and chance to ensure that it is conducted with the highest standards. Where appropriate, the SAB suggested improvements or additions to the research team - from inclusion of a Co-PI having specific disciplinarian credentials that would enhance the research effort, to offering suggestions of organizations that might shed additional light and enhance the standards and procedures proposed in the effort. The SAB also strongly encouraged inclusion of graduate students in research teams to promote training and foster development of technical expertise in cutting edge technologies.

Commitment to Ensuring Quality Research

The Board continued its key focus on assisting SERDP to ensure that SERDP-supported projects meet the highest standard of technical and scientific quality. The SAB addressed this issue from three avenues.

- First, the members strongly endorsed the established proposal review process. The SAB firmly supports SERDP's procedure to have each and every proposal reviewed by at least three Peer Reviewers that are experts in the discipline most closely related to the proposal's technical approach. All Peer Review comments are forwarded to the SAB prior to their meetings and are used extensively by the members during proposal discussions with the PI. These review comments complement the Board members' already diverse and deep technical expertise.

- Second, the members encouraged close coordination between projects that address related problems. In this sense, the Board evaluated projects on more than just the basis of their individual scientific merit and DoD relevance, putting increasing emphasis on coordination and leveraging between projects to ensure that related efforts indeed complement each other. As demonstration of this emphasis, the Board voiced its support for the use of a Technical Advisory Committee for "umbrella"-type projects, i.e., those that are a conglomeration of subprojects and centrally managed by a laboratory or agency representative. Projects in this category include the Federal Integrated Biotreatment Research Consortium, the Next Generation Fire Suppression Technology Program, and the SERDP Ecosystem Management Program.

Technical Quality Control is a recurring theme for the Scientific Advisory Board.

- Third, the Board fully supported the mid-year In-Progress Review of each project by the Technical Thrust Area Working Groups (TTAWG). While the SAB's primary function is to assess the technical aspects of SERDP projects, the Board has insufficient time to conduct a thorough technical evaluation of each ongoing project. The TTAWG is the appropriate group to perform this assessment. However, often times SAB members did attend and participate in some of the mid-year review meetings.

In a related matter, the SAB acknowledges that specific projects are funded at the recommendation of Congress. These projects were briefed to the Board, and the SAB appreciates the opportunity to assess these projects and offer suggestions to strengthen the effort; however, the Board is concerned that its review of these projects should not be viewed as a tacit endorsement. While the Board did recognize some limited elements of merit in one congressionally directed effort that was approved for funding by SERDP for FY 2001, the Board did recommend against funding it because it did not meet the SERDP definition of basic or applied research. Conversely, those Congressional interest areas that were opened up to competition and subjected to the same review requirements as other proposal efforts were welcomed by the SAB. Specifically, they approved all proposals that were submitted in response to a Congressional interest area under competitive terms.

Commitment to Technology Transfer

The SAB continued to emphasize technology transfer potential as an important criterion for evaluating proposals. Technology transfer is one of the SERDP Keys to Success, and the Board members continued their keen interest in the role of the military Services and eventual users of the technologies being developed.

Of particular interest to the Board was the improvement in the documentation and accountability of the National Environmental Technology Test Site (NETTS) Program. Having supported dozens of technology developments, tests and demonstrations over the last seven years, NETTS has appropriately and adequately documented these events and made them available for public review and use by interested researchers and developers. All projects now are summarized in a one page fact sheet that can be viewed by accessing the NETTS webpages through the SERDP home page website. The NETTS program has improved immeasurably due to these accomplishments and has contributed significantly in several characterization and remediation technology areas.

Complete technical reporting, including publications in the peer-reviewed literature as well as SERDP-required interim and final technical reports, was a metric used to determine project technical achievement and management acumen. The SAB fully supported SERDP's requirement for annual/interim technical reports and a final technical report upon completion of the project. These reports constitute technical progress to date, whether successful or not, on each project's technical approach. According to the Board, the value of "negative results" cannot be overstated, and SERDP projects should clearly state their progress and publish these results to facilitate further research.

The SAB continued its participation in the planning and execution of the annual *Partners in Environmental Technology* Technical Symposium and Workshop sponsored by SERDP. During strategy discussions at SAB meetings, the members offered comments on the overall theme of the Symposium and suggestions for technical session topics and plenary and session speakers. SAB members continued the tradition of active involvement in the planning and execution of breakout sessions. At the December 1999 event, four members served as technical session Chairs (Dr. Braden Allenby, Dr. Patrick Atkins, Dr. Raymond Loehr, and Dr. Perry McCarty) and Dr. Herb Ward served as Keynote speaker in the technical session on New Cleanup Protocols. The Board continued to demonstrate its commitment to involvement at the latest Symposium held in November 2000, with Dr. Jean'ne Shreeve serving as a technical session chair of the Green Chemistry session, and Dr. Braden Allenby providing a stimulating keynote address during the Strategy Pollution Prevention session. The active involvement of the SAB was a significant contributing factor to the overall success of the Symposium.

Areas of Opportunity

In the past the SAB has suggested areas of opportunity for SERDP investment. Often, these areas prove to become the focus of a national or world-wide research effort. Examples of research that commenced at the suggestion of the Board are: researching the toxic effects and emissions characteristics of PM 2.5; researching the fate and transport aspects of MTBE, the pervasive fuel oxygenate additive, and the characteristics and hazards associated with ammonium perchlorate. Due to their proactive thinking, SERDP was able to get a head start on understanding each phenomenon and initiating research to resolve associated issues.

During FY 2000 the SAB devoted considerable energy to reviewing candidate topic areas for future workshops. This discussion resulted in a recommendation to the SERDP Executive Director to convene a workshop during FY 2000 devoted to Cultural Resources Management (CRM). A workshop on CRM was held during the summer of FY 2000. Similar to previous SERDP workshops, it assessed the state of the science, identified gaps in technical knowledge, and determined strategic investment opportunities for DoD/SERDP. The results of this workshop included preparation of several Statements of Need on this topic.

Consistent with past practice, the Executive Director solicited the advice of the membership regarding his proposed allocation of funds among the four Thrust Areas for FY 2001. The Board was fully supportive of the proposed profile and general trends of investment within each of the four Thrust Areas.

Project Recommendations

During FY 2000, the SAB reviewed 50 proposals/projects, 35 of which were new start efforts and 15 of which were continuing projects. Of these 50 efforts, 17 requested FY 2000 funds totaling $14,439,000 and the remaining 35 projects requested $18,299,000 of FY 2001 funds. The Board recommended against funding one Congressional Earmark project. A summary of all projects reviewed and the results of their deliberations may be found in Figure I-6.

At the September 2000 Council meeting, Dr. C. Herbert Ward, Chair of the Scientific Advisory Board advised the Council of their emphasis on enhancing the research initiation process, ensuring quality research, and fostering technology transfer to the users in the field. He was particularly pleased that proposal and project quality continue to increase and much can be attributed to an excellent and comprehensive in-process review. The independent peer review component has ensured technical quality. His encouragement reassured Council members that the Program is continuing to take the correct measures and is proceeding appropriately.

Executive Director and Program Office

Increased Emphasis on Unexploded Ordnance

For FY 2001, the Executive Director has elected to identify UXO as a separate subthrust within the Cleanup Thrust Area. This was due to the significant technical challenges and potentially large liability for the DoD, its associated increase in funding on research efforts to address UXO detection, and the fact that the technologies involved in UXO detection are discretely different than those used in conventional cleanup. SERDP will continue to coordinate its UXO research efforts with the DoD's Joint UXO Center of Excellence and keep abreast of new initiatives developed with the Counter Mine efforts, such as found within the Multiple University Research Initiative, or MURI. Furthermore, the UXO Program plan will undergo a thorough peer review to ensure that it properly characterizes the broad problem, establishes clear and logical goals, and identifies specific, relevant, near-term technical objectives.

Proposal Solicitation and Selection

SERDP takes pride in the fact that funds for new starts are available to industry, academia and Federal researcher alike, and the Council continues to be pleased with SERDP's ability to reach out to a broader pool of researchers through a Broad Agency Announcement. SERDP again extended two solicitations – a "Core" solicitation that has traditionally been used to develop the annual program and a SEED solicitation. The SEED Program is designed to provide initial funding for high-risk, high-payoff proof-of-concept projects. Funding is limited to a maximum of $100,000 for up to one year. Successful efforts may compete for additional funds in the following years. Additionally, SERDP is occasionally requested to fund Congressional interest programs. In response to a special request by Congress to fund efforts in ecotoxicity research, SERDP crafted a SON to address this issue and selected proposals on a competitive basis. This process ensured that the DoD received valuable products for these limited additional appropriations.

Project No.	Recommendation				FY00 Meeting Date				New Starts	Continuing Projects
	Fund		Not Fund		1	2	3	4		
	FY00	FY01	FY00	FY01	Oct-99	Mar-00	Aug-00	Sep-00		
					Cleanup Thrust Area					
CU-861	$ 290				Oct-99					●
CU-863	$ 670				Oct-99					●
CU-864	$ 462				Oct-99					●
CU-866	$ 507				Oct-99					●
CU-1124	$ 455				Oct-99	Mar-00				●
CU-1165	$ 355				Oct-99				●	
CU-1166	$ 287				Oct-99				●	
CU-1199		$ 291					Aug-00		●	
CU-1200		$ 154					Aug-00		●	
CU-1201		$ 341					Aug-00		●	
CU-1203		$ 224					Aug-00		●	
CU-1204				$ 439			Aug-00		●	
CU-1205		$ 135					Aug-00		●	
CU-1206		$ 154					Aug-00		●	
CU-1207		$ 500					Aug-00		●	
CU-1208		$ 136					Aug-00		●	
CU-1209		$ 497					Aug-00		●	
CU-1210				$ 387			Aug-00		●	
CU-1212		$ 306						Sep-00	●	
CU-1213		$ 402						Sep-00	●	
CU-1214		$ 309						Sep-00	●	
					Conservation Thrust Area					
CS-1098		$ 890				Mar-00				●
CS-1114	$ 2,656	$ 2,526			Oct-99	Mar-00				●
CS-1185		$ 254						Sep-00	●	
CS-1186		$ 100		$ 300				Sep-00	●	
CS-1187				$ 153				Sep-00	●	
CS-1188		$ 350						Sep-00	●	
CS-1189		$ 300						Sep-00	●	
					Compliance Thrust Area					
CP-819*			$ 2,000			Mar-00			●	
CP-1190		$ 172						Sep-00	●	
CP-1191		$ 450						Sep-00	●	
CP-1192				$ 375				Sep-00	●	
CP-1193				$ 215				Sep-00	●	
CP-1195		$ 185						Sep-00	●	
CP-1197		$ 604						Sep-00	●	
					Pollution Prevention Thrust Area					
PP-1059	$ 3,000	$ 2,600				Mar-00				●
PP-1109		$ 1,000				Mar-00				●
PP-1110	$ 279				Oct-99					●
PP-1111	$ 693				Oct-99					●
PP-1113	$ 1,200				Oct-99					●
PP-1119	$ 480				Oct-99					●
PP-1133		$ 1,200				Mar-00				●
PP-1139	$ 329				Oct-99					●
PP-1147	$ 576				Oct-99				●	
PP-1152	$ 200				Oct-99				●	
PP-1179		$ 728						Sep-00	●	
PP-1180		$ 169					Aug-00		●	
PP-1181		$ 578					Aug-00		●	
PP-1184		$ 460						Sep-00	●	
PP-1198		$ 415						Sep-00	●	
TOTALS	**$ 12,439**	**$ 16,430**	**$ 2,000**	**$ 1,869**					**35**	**15**

* Congressional Earmark

Figure I-6. Summary of Proposals Reviewed by Thrust Area.

In developing the FY 2001 program, 23 SONs were prepared, eight of which were specifically for the SEED program. All 15 Core SONs, were made available to the private sector via a Broad Agency Announcement.

The Core solicitation responded with 197 preproposals that were submitted by non-Federal participants. Of the 80 full proposals that were requested, 18 were selected for funding resulting in a 23 percent selection rate. This figure exceeded the Council's target of 20 percent and was much greater than that experienced in other programs, such as those funded by the National Science Foundation. The Federal sector submitted 81 full proposals of which 12 were selected for a 15 percent selection rate. Figure I-7 depicts the distribution of Core proposals selected during the FY 2001 program development process.

Thrust Area	No. of Statements of Need	No. of Proposals Selected	SOURCE			Approximate Value (Thrust Total)
			Federal	Academia	Private	
Cleanup	**5**	**14**	**5**	**7**	**2**	**$ 4.9 million**
Compliance	**3**	**6**	**2**	**2**	**2**	**$ 2.2 million**
Conservation	**3**	**5**	**2**	**3**	**0**	**$ 1.5 million**
Pollution Prevention	**4**	**5**	**3**	**0**	**2**	**$ 4.0 million**
Total	**15**	**30**	**12**	**12**	**6**	**$12.6 million**

Figure I-7. FY 2001 Core New Start Proposal Distribution by Thrust Area.

The solicitation for FY 2001 SEED proposals resulted in the submission of 106 proposals. Twenty percent were received from industry, 30 percent were from academia, and 50 percent came from Federal sources. While only ten proposals were selected for funding, each exhibited the prerequisite characteristics of innovativeness, high risk and potentially high payoff. Figure I-8 depicts the distribution of all SEED proposals selected during the FY 2001 program development process.

Thrust Area	No. of Statements of Need	No. of Proposals Selected	SOURCE			Approximate Value (Thrust Total)
			Federal	Academia	Private	
Cleanup	**2**	**6**	**6**	**0**	**0**	**$ .6 million**
Compliance	**1**	**2**	**1**	**0**	**1**	**$ .2 million**
Conservation	**1**	**0**	**0**	**0**	**0**	**$ 0**
Pollution Prevention	**4**	**2**	**0**	**1**	**1**	**$ .2 million**
Total	**8**	**10**	**7**	**1**	**2**	**$ 1.0 million**

Figure I-8. FY 2001 SEED New Start Proposal Distribution by Thrust Area.

Technology Transfer

Successful technology transfer may be used as a metric to measure the success of the Program. While having funded over 300 individual projects, not all have been technically successful, as would be expected for a research program. For those projects that were successful, several avenues were taken to ensure that the diligent efforts of the research teams were transitioned to either higher development programs or implemented directly into field use.

Technology transfer and transition continued to be a primary area of focus during annual project reviews by both the SAB and the TTAWGs. Principal investigators were tasked to prepare Annual Technical Reports that serve as a fundamental baseline of technical progress. At the end of each project, a Final Technical

Report is required for each effort. These reports are maintained in a SERDP library and referenced on the SERDP website. Additionally, they are entered into the Defense Technical Information Center (DTIC) in both a hardcopy and electronic version. DTIC provides all researchers with copies of these reports. Recently, SERDP has become a partner in the new EnviroScience Electronic Print (e-Print) Service. The Environmental Science Electronic Print (e-Print) Service is a joint project of DOE's Environmental Management Science Program (EMSP), the EPA Office of Research and Development (ORD), the DoD's Environmental Security Technology Certification Program (ESTCP), and SERDP. e-Print uses EPA's Environmental Information Management System to collect, store and access published and unpublished manuscripts, conference papers, presentations and posters. This joint effort should have the result of enhancing scientific collaboration; speeding the dissemination of research findings; providing effective access to relevant research across the agencies.

The SERDP website also maintains links to websites developed by SERDP researchers. SERDP also has posted Fact Sheets on the website for every SERDP funded project. The Fact Sheet includes summaries of the technical accomplishments and potential benefits of each project.

Each year, SERDP in cooperation with ESTCP hosts the *Partners in Environmental Technology Technical Symposium and Workshop*. This event has, for the past five years, attracted hundreds of researchers, technology developers and users, and regulators to meet in a collegial and informative setting. Partners has historically been used to highlight successful SERDP projects, but more recently, it has been a venue to showcase related technology efforts from all sources, both Federal and private alike.

In November 1999, the annual Partners in Environmental Technology Technical Symposium and Workshop sponsored by SERDP once again succeeded in providing an excellent technology transfer and networking forum for researchers, scientists, and engineers from both the Federal laboratory system and the non-Federal sector alike. Our venue focused on Sustainable Development and encouraged meeting today's needs while preserving our future. This event brought 542 technology developers and implementers together, as well representatives from the policy, programmatic, regulatory, academic, and industrial sectors. The Executive Director issued its first SERDP Project of the Year awards that were awarded to the best projects in each of the four Thrust Areas. These awards have successfully attracted the attention of the scientific and engineering community around the globe and have measurably helped to either transition this technology into higher development programs, or implement its use in field applications. This conference, which has received numerous accolades, will continue to be enhanced to serve as a significant technical, educational and technology transfer event.

Plans for FY 2001

Given stable funding from the Council and DoD, SERDP plans to Plans to continue on its current track of success. Many of the initiatives of past years have been institutionalized as standard Program procedures. SERDP plans to continue to do the following:

- Continue to provide world-class research in response to the Department's highest priority environmental needs while serving in its role as the DoD Corporate Environmental R&D program.

- Continue non-Federal sector direct participation via Broad Agency Announcements for the solicitation of FY 2002 proposals in response to Statements of Need (See Appendix E).

- Continue external peer review for evaluating FY 2002 proposals received from both the Federal and non-Federal sectors.

In FY01, SERDP will continue to seek world-class research through a competitive process.

- Continue the use of Technical Advisory Committees to assist the research teams of large umbrella projects to focus and integrate their efforts.

- Continue to bridge technology from Science and Technology through to Dem/Val by conducting annual In-Progress Reviews in conjunction with ESTCP.

- Conduct the annual Technical Symposium and Workshop, focusing on technology transfer and increasing awareness of SERDP and SERDP-related efforts within the DoD user community.

- Collaborate with EPA (ORD) and DOE (EMSP) to fully implement the e-Print Service with the objective of making as many SERDP Final Technical Reports available as possible.

- Promote technology transfer on the SERDP website by providing summaries of SERDP funded technology and links to additional information about each project.

II. SIGNIFICANT ACCOMPLISHMENTS

Introduction

The ongoing mission of SERDP is to provide solutions to new or persistent environmental matters of concern to the DoD and the DOE. SERDP has responded to those concerns by supporting more than 320 environmental science and technology projects since the program's inception in 1991 in the areas of cleanup, compliance, conservation, and pollution prevention. These projects have enabled DoD installations to meet their environmental responsibilities using cost-effective and innovative methods. During FY 2000, SERDP continued to play a critical role in the development of science and technology that supports the DoD's environmental security goals.

Several of SERDP's most significant accomplishments during FY 2000 are described in this section. While these projects represent only a small selection of the many innovative projects supported by SERDP, they show the breadth and depth of the program and highlight the types of major technical advances resulting from focused research and development. Moreover, these accomplishments demonstrate potential cost savings while simultaneously maintaining mission readiness when new technologies become fully implemented. Appendices A through E provide a summary of each SERDP project funded in FY 2001 and every new initiative planned for FY 2002.

Cleanup Accomplishments

Unexploded Ordnance Detection

New technologies capable of detecting UXO with high detection rates and low false alarm rates are required to drastically reduce the cost of site characterization and cleanup. These technologies will include new sensor technology and data fusion and interpretation techniques.

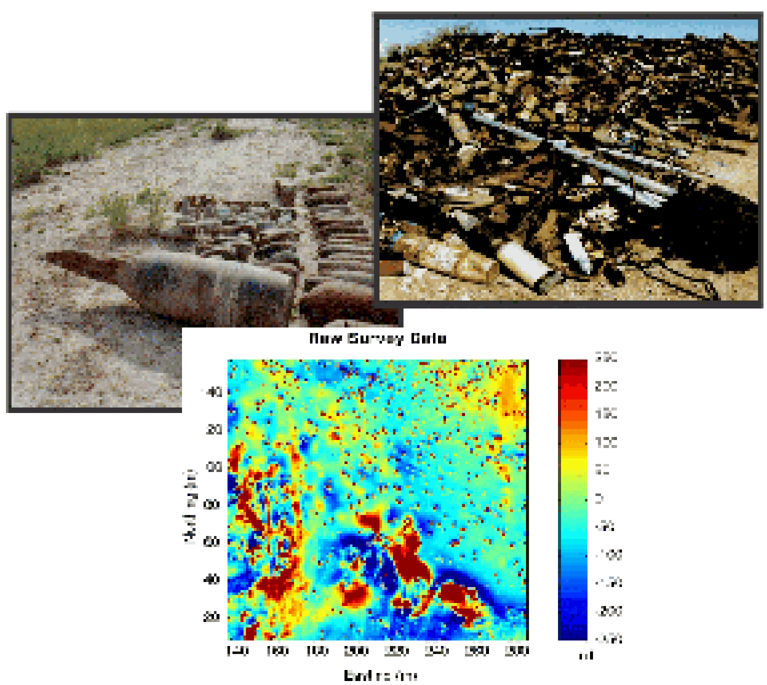


Figure II-1. Along with UXO (Top Left), Various Pieces of Scrap Materials and Natural Items (Top Right) Are Found on Ranges and Contribute to the Vast Numbers of False Alarms Detected by Sensors as Depicted in the Raw Survey Data.

Several different types of sensors are currently being explored for the detection and identification of surface and buried UXO, including electromagnetic induction, magnetometer, radar, and seismic sensors. In most field environments, UXO items are found amongst extensive surface and sub-surface scrap and shrapnel from ordnance. As a result, traditional approaches for UXO detection experience severe difficulty distinguishing buried targets from man-made clutter, thus limiting the ability to detect UXO and leading to many and costly false alarms. Figure II-1 depicts typical UXO and clutter that researchers encounter in the field and as they appear as anomalies in UXO-contaminated site surveys.

A Duke University team is performing **Statistical Signal Processing with Physics-Based Models: Multi-Sensor UXO Detection and Identification (CU-1123)** and has undertaken rigorous phenomenological modeling of electromagnetic wave propagation and scattering at ultra-wideband radar and electromagnetic induction (EMI) frequencies. The research team made significant progress in FY 2000 and was awarded SERDP's Cleanup Project of the Year. Since its initiation in FY99, this project has sought to delineate those phenomenological features that most discriminate UXO targets from manmade clutter. The research team has collaborated with current SERDP-sponsored organizations Army Research Laboratory (ARL), Naval Research Laboratory (NRL), and a private sector research firm to successfully reduce the false alarm rate of UXO detection sensor systems.

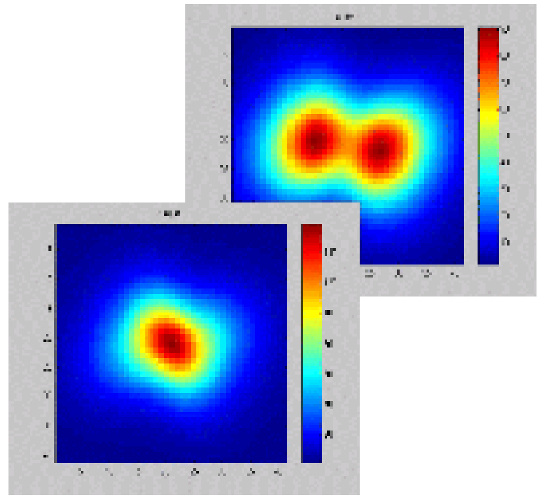


Figure II-2. Comparison between Clutter (Upper) and Ordnance (Lower) by Exploiting the Physics of Target and Clutter Sensor Profiles.

In FY 2000, phenomenological models have been developed and used to predict electromagnetic induction, magnetometer, and radar responses to arbitrary ordnance objects and representative clutter items. The team verified the accuracy of the models by comparing model predictions to data gathered in the field with the various sensors, and thus illustrated that these models can be used to develop and train our statistical signal processing algorithms, as depicted in Figure II-2. By exploiting the physics of target and clutter sensor profiles, and environmental uncertainties with enhanced signal processing for each sensor, we can now answer the question, "Which clutter objects are likely to cause false alarms?"

The team pursued development of sensor-fusion techniques that can simultaneously exploit richness and diversity of the phenomenology underlying multiple sensors. Data fusion techniques were applied to NRL's Mobile Towed Array Detection System (MTADS) field data measured during the Jefferson Proving Ground-IV experiment. The "fused" data from both magnetometer and EMI collected data from MTADS represents a true improvement in the probability of detecting UXO versus a false positive. Collectively, these modeling, statistical processing and sensor fusion techniques have resulted in significant performance improvements over those obtained by previous non-statistical techniques. Through a series of comparisons of sensor-based algorithms, output of statistical algorithms, and ground truth, analysts can now better determine UXO from scrap metal and other false positive artifacts. The recent successes of the Duke research team have provided the field users with:

- Improved discrimination between UXO and non-UXO items,
- Marked reductions in the false alarm rate for UXO while maintaining a high probability of detection, and
- The potential for large costs savings and an enhanced level of confidence for DoD as it clears UXO from its lands.

Remediation of Explosives in Groundwater

Groundwater contaminated with explosive compounds represents one of the most challenging environmental problems for the DoD. Explosive compounds of concern include 2,4-DNT, 2,6-DNT, TNT, RDX, and HMX. Under favorable conditions, many of these nitrated compounds react rapidly with zero-valent iron (Fe^0), which suggests that permeable reactive barriers containing zero-valent iron (FePRBs) might be useful in the remediation of groundwater contaminated with explosives. Unfortunately, reduction of the nitrated compounds by iron metal produces aromatic amines as the primary products, and these products are still substances of regulatory concern. As a result, full-scale implementation of FePRBs to treat explosive contaminated groundwater has been delayed until effective treatment for the amines could be developed. In FY 2000 SERDP funded two projects under the SERDP Exploratory Development (SEED) Program to develop a proof of concept understanding of how two explosive compounds could potentially be degraded using FePRBs in conjuction with a subsequent treatment process for the amines.

Royal Demolition Explosive (RDX) is a contaminant of major concern, because it is a suspected human carcinogen and is known to cause epileptic seizures. Because of its recalcitrance to microbial degradation, low volatility and high mobility in aquifers, clean-up of RDX contaminated sites is a challenging problem. Through the SERDP SEED project **Fe^0-Based-Bioremediation of RDX-Contaminated Aquifers (CU-1175)**, researchers at the University of Iowa successfully conducted proof-of-concept experiments for a new and efficient method to remediate RDX-contaminated aquifers, based on combining a novel chemical process using zero-valent Iron (Fe^0) with a promising bioremediation approach using in situ reactive zones. During the year long study the project team worked towards delineating the applicability and limitations of biologically-active Fe^0 barriers to intercept and destroy RDX plumes with a focus on obtaining information regarding the fate of RDX and mineralization kinetics. During the study the project team identified the following:

(1) RDX degrades faster than other pollutants commonly treated with iron barriers,

(2) The combination of anaerobic bacteria with iron is synergistic in terms of the rates and extent of mineralization, and this synergism is due in part to hydrogen (H_2) production during iron corrosion, which stimulates reductive biotransformations,

(3) Bacteria can enhance iron reactivity by reductive dissolution and activation of oxides that passivate the iron surface,

(4) Converging lines of evidence suggest that a concurrent or sequential combination of iron and biological treatments may be appropriate to intercept and destroy RDX plumes. As an example, (Figure II-3) RDX plumes could use bioaugmented PRBs and rely on natural attenuation of products that break through, if any.

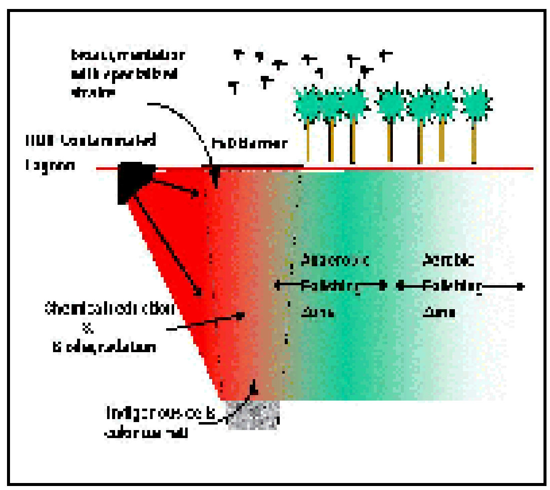


Figure II-3. Integrated Fe^0-Bioremediation System to Intercept and Degrade Redox-Sensitive Pollutants.

In another SERDP SEED funded project entitled **In-Situ Remediation of Explosives Contaminated Groundwater with Sequential Reactive Treatment Zones (CU-1176)**, researchers from the Oregon Graduate Institute set out to test various methods of treating the TNT effluent from an Iron Permeable Barrier (FePRB) by in situ chemical and/or enzymatic oxidation. Priority was given to oxidative treatments that could be applied after an FePRB, in a configuration that is called Sequential Reactive Treatment Zones (SRTZ) (Figure II-4). Researchers planned to test a variety of oxidants (air, oxygen, hydrogen peroxide), types of delivery systems (sparging, direct injection, passive infiltration), and process variables (flow rate, pH, carbonate, iron). Columns were prepared containing various types and quantities of iron metal and then exposed to various solutions of TNT. To the surprise of the researchers, many of the columns exhibited complete TNT degradation with no reaction products detected in the effluent. The conclusion of this study suggest that full-scale FePRBs (alone) may be an effective remediation tool for TNT and possibly other nitrated compounds.

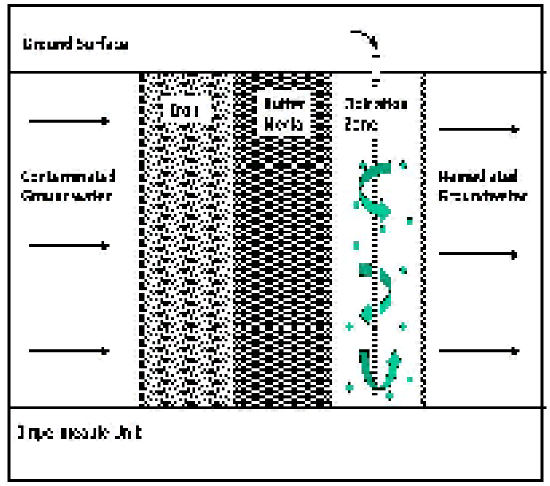


Figure II-4. Implementation of a Sequential Reactive Treatment Zone (SRTZ).

The research team has initiated a range of follow up studies to explain the important differences between the results of batch and column tests, and to reassess the robustness of simple FePRBs for treating TNT contaminated groundwater. The research team has found that break-through of TNT and its reduction products only occurs at unrealistically high flow velocities and/or low loadings of iron. Little evidence for TNT or its transformation products has been found so far by eluting the columns or extracting the iron.

Based on the results from CU-1175 and CU-1176, follow-on work is planned to generate the data needed to scale up these processes for field testing.

Remediation of Ammonium Perchlorate in Groundwater

Ammonium perchlorate is used in a number of strategic, tactical, and space systems as the primary solid rocket propellant oxidizer. A number of DoD facilities face the challenge of remediating groundwater contaminated with perchlorate due to environmental releases of ammonium perchlorate that occurred during propellant manufacturing, testing and disposal activities. The perchlorate anion is extremely soluble in water and therefore exceedingly mobile in aqueous systems. It can persist for many decades under typical groundwater and surface water conditions, because of its resistance to react with other available constituents. The primary human health concern related to perchlorate is that it can interfere with the thyroid glands' ability to utilize iodine to produce thyroid hormones.

Biological treatment of perchlorate has been identified as the most practical and economically feasible method for the in-situ treatment of this contaminant. Such technologies would take advantage of the unique metabolic capabilities of perchlorate-reducing bacteria which can use perchlorate as an electron acceptor for growth, reducing it to innocuous chloride. However, to date, there is very little information available on the microbiology of perchlorate reduction and only a few microorganisms have been identified that have the potential metabolic capabilities to degrade perchlorate. In FY 2000, SERDP funded three projects to focus on basic microbiological, bench-scale, and field-scale research to develop approaches for the cost effective in-situ treatment of groundwater contaminated with ammonium perchlorate. The combined results of these three projects represent significant advancements in the understanding of perchorate remediation and the development of remediation strategies for ammonium perchlorate.

Through the SERDP project **In-Situ Bioreduction and Removal of Ammonium Perchlorate (CU-1162)**, researchers from Southern Illinois University are obtaining a better understanding of the microbiology involved in microbial perchlorate reduction and removal. The factors controlling the applicability of microorganisms to the in-situ treatment of ammonium perchlorate contamination of natural water supplies are being determined. In addition, this work will result in the development of molecular tools required for the application of in-situ bioremediation strategies to treat perchlorate contamination in the environment.

One physiological feature common to all of the perchlorate reducing bacteria isolated to date is the ability to dismutate or change chlorite to chloride and oxygen, which allows for perchlorate degradation. Previous studies have identified a single enzyme, chlorite dismutase that is responsible for this metabolism. Since commencing this project, the research team set out to identify if all perchlorate reducing bacteria contain a conserved chlorite dismutase enzyme. If this enzyme is conserved in all perchlorate reducing bacteria it offers a unique target for a gene probe specific to all perchlorate reducing bacteria in the environment and this will aid in identifying perchlorate reducing bacteria at a site. In this project's first year, the research team has already isolated and characterized more than thirty perchlorate-reducing bacteria (see Figure II-5) from diverse environments. The research team also found that most perchlorate-reducing bacteria do contain a conserved chlorite dismutase enzyme. Follow on studies will focus on the effectiveness and robustness of these microbial populations.

Figure II-5. Example of a *Dechlorosoma Suillum* Strain that Is Capable of Perchlorate Degradation.

In a two-year SERDP-funded project entitled **In Situ Bioremediation of Perchlorate (CU-1163)**, researchers from Envirogen, Inc. are exploring the next step in developing ammonium perchlorate bioremediation systems. The objective of this project is to identify the key environmental factors in subsurface environments that inhibit perchlorate degradation in groundwater. Using several microbial strains from project CU-1162 with the ability to degrade perchlorate, laboratory experiments using aquifer microcosms and flow-through model aquifers have been conducted in order to evaluate treatments for stimulating perchlorate degradation. The results from the micocosm studies have shown that addition of an electron donor is a very promising in-situ approach. Equally as important, the research team also identified answers to the overriding question of why perchlorate is not easily degraded in many groundwater aquifers. They found that low pH and high levels of oxygen may be the main factors that inhibit perchlorate degradation.

In Situ Bioremediation of Perchlorate-Impacted Groundwater (CU-1164) is the third perchlorate project mentioned in this section. Researchers from GeoSyntec Consultants Inc. are building on the data generated in the other two perchlorate projects to conduct a small-scale field pilot test to demonstrate that perchlorate can be biodegraded under field conditions. Initial design and cost data for potential technology scale-up and validation will also be generated. During the first year, this project focused on selecting sites contaminated with perchlorate and collecting soil samples to assess the ubiquity of perchlorate reducing organisms. Researchers were able to stimulate perchlorate biodegradation at selected sites by using acetate, molasses and oleate as electron donors. The project team found that there generally was no acclimation period, and that intrinsic biodegradation was observed at several sites. The research team also found that high nitrate and sulfate can slow down the biodegradation process. The research team hopes to develop a robust, reliable and cost-effective treatment technology for perchlorate-impacted groundwater at DoD, DOE and defense contractor facilities.

MTBE Plume Containment and Control

The SERDP National Environmental Technology Test Site (NETTS) program is comprised of a network of well-characterized demonstration sites at DoD installations. The goal of this SERDP-funded program is to provide accessible, well-supported field locations for project proof-of-principle tests, applied research, and comparative demonstrations, as well as to facilitate transfer of innovative environmental technologies from research to full-scale use. Established in FY93, the SERDP NETTSs are available to DoD, Department of Energy (DOE), and EPA users, as well as other agencies and the private sector. The following are the Test Locations that constitute the NETTS Program are:

- Naval Construction Battalion Center (CBC) Port Hueneme in California;
- McClellan Air Force Base (AFB) also in California; and
- Dover AFB in Delaware.

Although many demonstrations were hosted at the NETTS sites during the last fiscal year, one key success in FY 2000 merits special recognition and is detailed below.

Methyl tertiary butyl ether (MTBE), a common fuel additive, is a chemical of concern at fuel release sites, specifically at those sites where releases have occurred since the early 1980s. Because it is highly mobile, extremely soluble, sorbs weakly to soil and aquifer materials, and has low natural degradation potential, MTBE often migrates downgradient farther and faster than other fuel components. There are some indications that MTBE is potentially toxic and potentially carcinogenic and imparts objectionable taste at concentrations as low as 5 parts per billion (ppb). Regulatory standards for MTBE in groundwater have yet to be set on a national level. However, preliminary guidelines and health advisories have suggested target levels in the 5 - 40 ppb range based on both health and aesthetic considerations. MTBE contamination of groundwater has the potential to be a significant remediation issue for the Department of Defense (DoD) as well as for the rest of the nation.

The National Test Site Location-Port Hueneme (CU-863) has established a network of environmental engineers, regulators, and experts from industry and academia to address MTBE remediation in soil and aquifers. During FY 2000, efforts have been made to address DoD, State of California, and EPA issues concerning sites contaminated with MTBE. A number of technologies and approaches have been evaluated at the NETTS to address the MTBE problem including air sparging, in-situ bioremediation, natural attenuation, and MTBE modeling. More significant benefits will be achieved indirectly as additional information is provided to the regulatory community on the role of natural attenuation for MTBE plumes. These NETTS initiatives were instrumental in the recent establishment of the joint U.S. EPA/U.S. Navy effort to conduct a multi-year program for the demonstration of new, innovative technologies for the treatment of MTBE in groundwater. It is expected that these efforts will provide critical technical cost and performance data to the end-users and the regulatory community. In-situ and ex-situ MTBE remediation alternatives found to be practicable and cost-effective when compared to conventional pump and treat (P&T) will be demonstrated at the Port Hueneme NETTS.

Real-Time DNAPL Detection

Dense non-aqueous phase liquids (DNAPLs) formed by chlorinated solvents pose the most widespread obstacle to cleanup at DoD/DOE facilities. Annual costs greater than $500,000 for containment and monitoring of a single DNAPL plume are typical. Locating DNAPL sources and reliably estimating their mass are crucial for cost-effective cleanup. Currently, no available method can accurately and efficiently define the subsurface distribution of chlorinated solvent DNAPLs. In the SERDP funded project **Negative Ion Sensors for Real-Time Downhole DNAPLs Detection, (CU-1089)**, researchers from Dakota

Technologies Inc. are working to develop a Site Characterization and Analysis Penetrometer System (SCAPS) probe that can detect, locate, and quantify the subsurface distribution of DNAPLs in the soil. A halogen specific detector (XSD) and a photoionization detector (PID) (see Figure II-6) were developed during the first two years of the project. During FY 2000 the project team worked towards enhancing the sensors and testing them in a established field site. Testing demonstrated that the largest single factor affecting stability of the baseline signal is temperature fluctuations of the XSD. The project team was able to over come this problem by developing a thermocouple that was imbedded into the XSD insulation to actively monitor the temperature of the XSD. Concurrent with the XSD signal. This temperature data is used to correct the baseline fluctuations. Further demonstration and validation of these sensors is planned to be conducted under ESTCP funding.

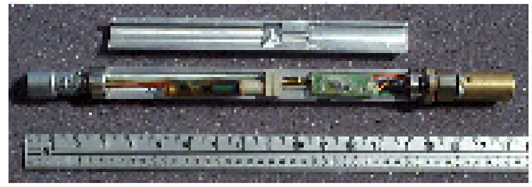


Figure II-6. Example of a Downhole Photoionization Detector (PID).

Compliance Accomplishments

Sustainable Ranges

Testing and training ranges are key elements in maintaining the capability and readiness of the U.S. Armed Forces. The current state of knowledge concerning the nature and extent of contamination and the fate of residues of energetic materials is inadequate to ensure sound management of ranges as sustainable resources. The primary objective of the SERDP project **Distribution and Fate of Energetics on DoD Test and Training Ranges (CP-1155)** is to provide the DoD with techniques to assess the potential for groundwater contamination from residues of high explosives (TNT, PETN, RDX, and HMX) at testing and training ranges (see Figure II-7). A research team from the U.S. Army Engineer Research and Development Center, Waterways Experiment Station is sampling and analyzing soils at military ranges to characterize the concentration, distribution and environmental transport parameters of energetic materials. These parameters will contribute to the evaluation of the fate and transport of residual contamination and the potential for groundwater contamination.

Figure II-7. SERDP Researchers Are Evaluating the Potential for Contaminant Releases from Energetics Residues on Testing/Training Ranges.

In the first year of this FY 2000 new start project, the research team successfully demonstrated a novel method to sample for energetic compounds. Ordnance was fired over a freshly fallen, uncontaminated snow cover, providing an effective means to: (1) visualize the "fallout" from individual blasts, (2) to sample energetic residuals without the matrix interferences normally present in soils, and (3) achieve an analysis free of contamination from historical ordnance firing. Surface soils also were collected from howitzer firing points, numerous artillery and mortar impact areas, as well as a hand grenade range. Analyses of soil samples to date have provided preliminary indications or the concentration and distribution of propellant contaminants as well as Composition B explosives (TNT, RDX, and HMX) in surface soils.

Wastewater Treatment

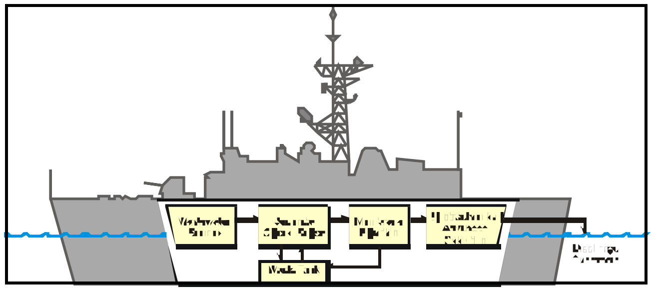


Figure II-8. Naval Electrodes Allow Energy-Efficient Oxidation of Organic Substances Dissolved in Wastewater before Discharge Overboard.

To comply with International Maritime Organizations Marine Pollution Convention (MARPOL) Annex V and other environmental regulations, U.S. Navy vessels require compact, energy efficient water purification technology that will allow wastewaters produced on board (bilge, gray, black, etc.) to be discharged overboard following purification. The current practice of using membrane filtration does not achieve the degree of purification required, and a final "polishing" process is needed prior to discharge overboard. An effective polishing process that is appropriate for shipboard use does not exist. Through the project **Electrochemical Advanced Oxidation Process for Shipboard Final Purification of Filtered Black Water, Gray Water, and Bilge Water (CP-1107)**, investigators at Sonoma Research Company are completing their final year of research on the development an electrochemical Advanced Oxidation Process (AOP) to be used as the final polishing step following membrane filtration of shipboard wastewater (see Figure II-8).

The complete system is able to determine current, DC impedance, AC impedance and the capacitance of the anode as a function of anode potential in a single test. Electrode coating methods have been thoroughly reviewed and approximately fifty test electrodes with precisely documented production histories were developed. This substantial inventory of electrodes will allow the investigators to identify the coating method that produces the best electrodes and specify methods that will produce full-sized electrodes. A provisional patent application that covers developments since the original patents was filed. In a demonstration of this process' effectiveness, cyanide in wastewater was successfully destroyed at pH 10. The reaction rate was monitored using a cyanide ion-specific electrode and proved to be consistent with kinetic parameters determined using other substrates. The transition from zero order kinetics to first-order kinetics as the reaction proceeded was clearly visible in the data, directly confirming the model of reaction kinetics.

Air Emissions and Control

The 1990 Clean Air Act Amendments (CAAA) require facilities to monitor and measure criteria air pollutants, such as nitrogen oxides (NOx) and particulate matter (PM), and hazardous air pollutants (HAP), the latter of which includes 189 individual toxic compounds. Many of these pollutants are emitted during DoD and DOE operations and need to be monitored and characterized in order for these facilities to maintain their permits. To reduce the costs associated with chemical analyses of these air emissions, DoD is seeking alternatives to traditional sampling and time-consuming analytical methods used to meet the current compliance monitoring requirements. Selected as the FY 2000 SERDP Compliance Project of the Year, **Laser-Based Spectrometers for Air Emissions Monitoring (CP-1060)** focuses on two technologies that appear to show the most promise - photoacoustic spectroscopy for monitoring organics and laser-induced plasma spectroscopy for monitoring the emissions of metals. An infrared (IR) spectrometer, based on the new, periodically-poled lithium niobate (PPLN) laser technology, was developed at Sandia National Laboratory to analyze organic air pollutants. The team from Oak Ridge National Laboratory (ORNL) developed a laser induced plasma spectroscopy (LIPS) with aerosol beam to detect toxic metals, such as metals and organo-metal compounds associated with airborne particulate matter.

The PPLN laser offers many advantages when compared to other laser materials for chemical sensing and spectroscopy. In particular, PPLN converts light from a fixed frequency to two tunable beams and can be made to tune over much of the mid-infrared region. This broad tunability is particularly important since many volatile organic compounds (VOCs) have a wide spectrum of absorbing features which cannot be distinguished without broad tuning. The high power output afforded by PPLN allows the use of photoacoustic spectroscopy, and the high efficiency enables the development of compact, portable sources. This combination of power, materials, and sensitivity offers unprecedented performance. Field tests of the photoacoustic spectrometer were recently completed by researchers from SNL at a paint shop in a particularly challenging measurement environment, as many types of VOCs were emitted and a water curtain was used to scrub the effluents before the analyzer and release to the atmosphere. With the combined broad and fine tuning capability of the PPLN based laser, VOCs can be both detected and speciated in the presence of high water vapor concentrations.

While recognized as a simple and effective laser spectroscopic technique, applications of LIPS to aerosol measurements have been limited, but have recently received renewed interests upon implementation of recent emissions regulations and ambient PM2.5 standards. The portable ORNL LIPS system has an in-situ extractive configuration unlike other systems. An aerosol beam focusing technique has been incorporated into LIPS. In a side-by-side comparison, no signal could be observed without aerosol beam focusing at a low laser energy, whereas a quantifiable signal was observed at a low excitation energy level with aerosol beam. In a field test of the portable LIPS system at an engine test cell, emissions were spiked with selected metals inside a dilution tunnel. Operating conditions were varied to simulate actual emissions that are known to be highly transient and complex with respect to chemical composition. The compact portable system yielded on-line analysis data with great precision in a small test cell under harsh environmental conditions. Further, no loss of reactive species, such as mercury(II), was experienced.

Both regulatory and economic incentives exist for implementing new pollution-control technologies for NOx and HAPs, including VOCs. Given the considerable regulatory pressure, e.g., the promulgation of a National Emissions Standard for Hazardous Air Pollutants (NESHAP) for NOx emissions in CY2000, new de-NOx technologies are being explored. Sources of NOx production within DoD and DOE include jet engine and cruise missile test cells (JETC & CMTC), fuel burning operations, diesel motor generators, and ordnance manufacturing and demilitarization. VOC sources include JETCs and CMTCs, manufacturing of propellants, explosives, and pyrotechnics (PEPs), and painting, coating, and paint stripping operations. In the SERDP project, **Development of Non-Thermal Plasma Reactor Technology for Control of Atmosperic Emissions (CP-1038)**, scientists and engineers from Los Alamos Laboratory, collaborated with those from the Army and Air Force Research Laboratory and McMaster University to evaluate non-thermal plasma (NTP) technologies for treating jet-engine test facility exhaust and other hazardous air pollutants. The removal of nitric oxide (NO) has been the primary focus of this project, with a secondary focus on HAP removal.

The focus of the project in FY 2000 included completing final design of individual components for the field-pilot equipment, fabricating the main corona radial shower (CRS) reactor (Figure II-9) and the NTP system equipment, installing it in a 20-foot trailer, and conducting field tests. A small pilot-scale field demonstration on NOx removal at Tinker Air Force Base demonstrated promising results under certain operating conditions.

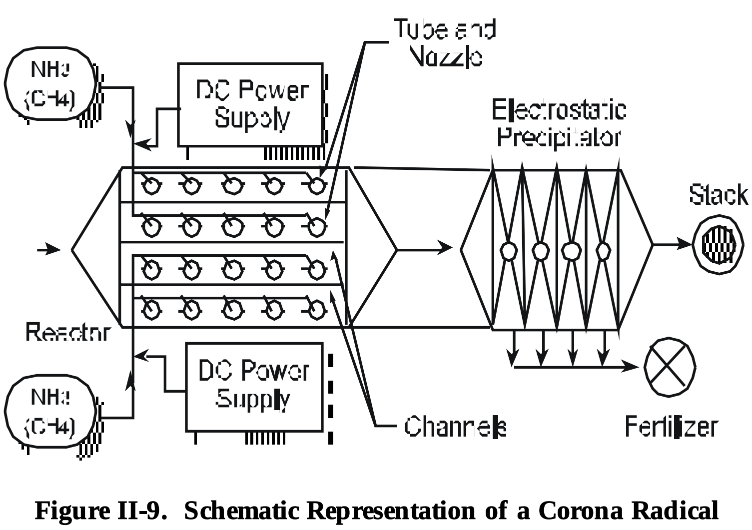


Figure II-9. Schematic Representation of a Corona Radical Shower (CRS) Reactor System.

In the field tests, 70-100% de-NOx was achieved with the CRS reactor operating primarily under oxidizing conditions.

Copper Measurement and Monitoring Marine Systems

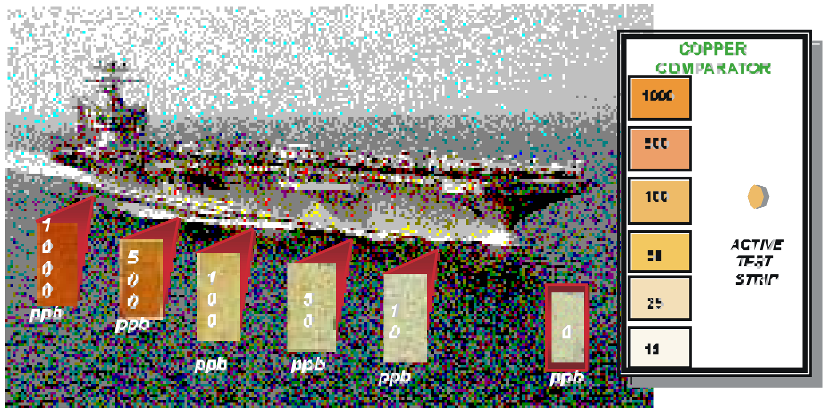


Figure II-10. Left: Actual Copper Test Strips Exposed to Varying Concentrations of Copper (I) with a Theoretical Release Profile from a Ship as It Passes through the Water. Right: Proposed Comparator Containing an Active Test Strip and Color Comparison Chart.

The Navy uses copper antifouling coatings on its ships to reduce or eliminate the presence of barnacles and algae that can impede the ship's speed and increase fuel consumption (up to 22%). The copper in these coatings, in the form of ionic copper [Cu(I) and (II)], is also of major environmental concern as it impacts nontarget marine and estuarine organisms. With the future implementation of the Uniform National Discharge Standards (UNDS), the ability to quickly and easily measure the toxic forms of copper contamination in a harbor and within shipyard hull cleaning facilities is important. **Use of a Nafion Membrane Probe for Quick, On-the-Spot Determination of Ionic Copper Contamination Levels in Natural Waters (CP-1160)**, an FY 2000 SEED project, has led to the development and simplification of an ionic copper detection device/method for use in the field. The project used a dosimeter probe composed of the polymer Nafion 117 impregnated with and without Bathocuproine (BCP) to assess its sensitivity to Cu(I). The proof of concept was demonstrated with the response to, and absorption of, Cu(I) by the membrane. Figure II-10 represents theoretical copper release profile and an example of a proposed comparator strip. Follow on funding should lead to a portable and effective detection and measurement device for copper in harbor waters.

Conservation Accomplishments

Ecosystem Restoration

Within the DoD, the military services are required to maintain and restore remaining native ecosystems across their natural range of variation. Furthermore, in support of the National Defense mission, the DoD must ensure long-term sustainability of military training and testing lands and waters. The characterization of plant resilience and the development of wear resistant plant cultivars for off-road traffic areas are important foci under the ecosystem restoration, research, and development opportunities.

The SERDP Project, **Identify Resilient Plant Characteristics and Develop Wear Resistant Plant Cultivars for Use on Military Training (CS-1103)**, has been extremely successful in breeding new, more resilient cultivars (see Figure II-11). Through the leadership of the Cold Regions Research and Engineering Laboratory of the U.S. Army Corps of Engineers and the efforts of its collaborators, three new germplasms have been developed: (1) 'CD-II' crested wheatgrass which is derived from the cultivar Hycrest; (2) RWR-Tetra-1 Russian wildrye [*Psathyrostachys juncea* (Fisch.) Nevski]; and (3) 'RoadCrest' crested wheatgrass [*Agropyron crestatum* (L.) Gaertn.], a rhizomatous cultivar. The plants resulting from these germplasms are more resilient to military training activities due to their resistance to drought and cold

Figure II-11. New Growth on Treated Soil.

temperatures, low maintenance requirements and seedling vigor. The germplasms are used to identify the genetic markers in other plants that have similar resilient characteristics to support further breeding studies. Another important attribute of these germplasms is that they are derived from native plant stocks growing at the DoD installations. This makes them highly credible and desired by the military land managers. Additionally, genetic material of one or more of these germplasms will be deposited in the National Plant Germplasm System, where it will be available for research purposes, including development and commercialization of new cultivars. Further information on the breeding research is available on http://www.crrel.usace.army.mil/gcd/research/breeding.htm.

Ecological Forecasting

The various ecosystems throughout the U.S. provide the training scenarios and realism for the DoD to maintain its military readiness. To sustain these ecosystems, decisions makers must take into account potentially interactive effects of natural variability and human induced change on ecosystem structure, function and productivity. A key role of science is to provide insights into the potential scale, direction, and nature of that change. SERDP-funded research and development in Ecological Forecasting is aimed at forecasting the ecological response to current and/or expected change. One of these efforts, led by the Desert Research Institute, is titled **Analysis & Assessment of Military & Non-Military Impacts on Biodiversity: A Framework for Environmental Management on DoD Lands Using the Mojave Desert as a Case Study (CS-1055)**. This SERDP project provided an analysis of the impacts of military and non-military stressors on patterns of biodiversity and related environmental resources in the western Mojave Desert region. It also provided a tool to develop alternative future scenarios based on these stressor impacts and various land use patterns. The approach consisted of determining and modeling habitat relationships to key species and assessing their management strategies. A landscape analysis was performed to determine the magnitude of change from 1972 to present. An example of the type of spectral images used to measure ecological change over time is shown in Figure II-12. Alternative future land use scenarios were modeled based on the selection of stressors, biodiversity, and other environmental issues. This effort provides the DoD with a model tool to evaluate impacts of both DoD and non-DoD stressors (such as off-road vehicle use and suburban development), thereby providing a capability to be a more effective negotiator of biodiversity and other ecosystem management issues with surrounding stakeholders.

Figure II-12. Representation of Effects of Alternative Land Use Scenarios in the Mojave Desert. Upper Left: Historical Trend Scenario. Lower Right: Full Build-Out Scenario.

Figure II-13. Modeling Approach Test Locations and Subjects.

DoD training and related activities on and adjacent to military lands often contribute to fragmentation of the landscape. The detrimental effects of habitat fragmentation on animal populations are widely documented. However, the development of practical tools to predict the effects of fragmentation and the design of appropriate mitigation efforts has progressed slowly, especially for DoD installations. The SERDP Project, **Predicting the Effects of Ecosystem Fragmentation and Restoration Management Models for Animal Populations (CS-1100)**, is being led by Northern Arizona University. This effort is developing species-specific models that predict the responses of mobile animal species in heterogeneous landscapes to changes in their habitats that may occur due to natural or man-made situations. Ponderosa pine forests and riparian environments on military lands are the habitats being addressed for species of passerine birds and butterflies. These species are used to test the generality of the modeling approach for mobile animals (see Figure II-13). The modeling effort connects life history characteristics and the responses of mobile animals to habitat fragmentation and restoration. Parameterization and validation of the model is based on ecological field measurements. This project represents a significant advancement in the understanding of the effects of fragmentation and in the design of mitigation measures. See the following website for more information: http://www.nau.edu/~envsci/sisklab/research_projects/EAM/index.htm.

Ecosystem Monitoring

Under the management of the U.S. Army Engineering Research and Development Center, the **SERDP Ecosystem Management Project (SEMP) (CS-1114)** continues to support DoD's commitment to maintain and improve the sustainability and native biological diversity of terrestrial and aquatic ecosystems by implementing a long-term, ecological monitoring program (see Figure II-14). The goal of SEMP is to provide knowledge, tools, and techniques to contribute to understanding and enhancement of the ecological role of military installations within their ecoregions. This umbrella-type project includes supporting multiple research and development efforts that are focused on the identification of ecological indicators, disturbance regimes and ecological thresholds, and adaptive management.

Figure II-14. SERDP's Ecosystem Management Project Provides Scientific Information and Tools to Assist Installations with Implementing an Ecosystem Approach to Their Land Management Issues.

The first set of research teams, beginning in 1999, are identifying and linking indicators of ecological change to processes that occur as a result of natural and/or military actions. In FY 2000, their efforts resulted in at least one year of sampling data and the initiation of preliminary analyses of these data. One project investigated the historical trends affecting candidate indicators by extracting data from historical documents and maps and converting them to a digital format for analysis. Beginning in FY 2000, two additional teams examined disturbance regimes and ecological thresholds by selecting studies sites and initiating sampling efforts. Monitoring transects and points were established for these teams as well.

As a compliment to the research efforts, SEMP's Environmental Characterization and Monitoring Initiative (ECMI) provides the design, development and demonstration of an ecological baseline-monitoring program at Ft. Benning. The objective of ECMI is to characterize the long-term spatial and temporal dynamics of key ecosystem properties and processes. In FY 2000, ECMI implemented its monitoring plan that includes monitoring hydrologic flux, biological productivity, biogeochemical cycling, decomposition, and biological diversity. Surface water monitoring sites were installed and the development of a groundwater monitoring system (including five monitoring wells) was initiated. The products of this research shall serve as the basis of data for all research projects, regardless of program origin, that use Ft. Benning.

A shared data repository was developed during FY 2000. Now, new data obtained from SEMP monitoring activities, research activities and from other installation efforts can be registered, indexed, accessed and shared from a common context. In addition, the repository helps ensure that high standards are maintained for data documentation, accuracy assessment and management.

A website has been established for SEMP under the Defense Environmental Network Information eXchange (DENIX) working group area. This website includes a calendar of activities, linkages to other sites, selected SEMP briefings and publications for review and for downloading, and a discussion forum. The SEMP newsletter is also available. The URL for this website is http://www.denix.osd.mil/SEMP.

Endangered, Threatened, and Sensitive Species

Research and development opportunities under the subthrust of Endangered, Threatened, and Sensitive Species continue to address current compliance requirements under the Endangered Species Act and National Environmental Policy Act. As concerns increase over the expanded presence of man-made sounds in the oceans [e.g., low frequency active (LFA) sonar and ship shock trials], only limited information on their effects on marine mammals is available. Actual sound frequency-intensity combinations are suspected of causing damage to the hearing of marine mammals.

The SERDP project **Information and Technology Tools for Assessment and Prediction of the Potential Effects of Military Noise on Marine Mammals (CS-1082)** was led by Navy's Space and Naval Warfare Systems Center in San Diego, California. This project developed information and tools to provide assistance in the assessment and prediction of military noise effects on marine mammals. Baleen whale sensitivity to low frequency sounds was predicted by combining anatomical measurements and state-of-art computer techniques to produce computational models of baleen whale hearing. These computational models ("WhalEar" models) provided predictions of the relative sensitivity of other whale species to different sound types to which the whales may be exposed. In combination with hearing information from various species, a computer model was developed that resulted in the first visualization of the hearing curve of a humpback whale.

This project also developed a process of mapping the location of whales and their seasonal variances by using signal processing techniques that automatically detect and classify whale calls that are recorded on existing Navy bottom-mounted hydrophone arrays. Figure II-15 shows photograph of a North Pacific Humpback Whale along with an example of its recorded song. Using this approach, areas of high blue and fin whale activity in southern California have been mapped, including seasonal changes in whale residency and migration routes. This project was recognized and awarded the SERDP Conservation "Project of the Year" Award for FY 2000 at the Partners in Environmental Technology Technical Symposium and Workshop held November 28 – 30, 2000. The project is leading the succession of research and development needed to advance the understanding of marine mammal hearing sensitivity and the impacts of military activities on these species. For more information, see the following websites:

- http://www.spawar.navy.mil/sti/publications/pubs/tr/1834
- http://www.spawar.navy.mil/sti/publications/pubs/tr/1835

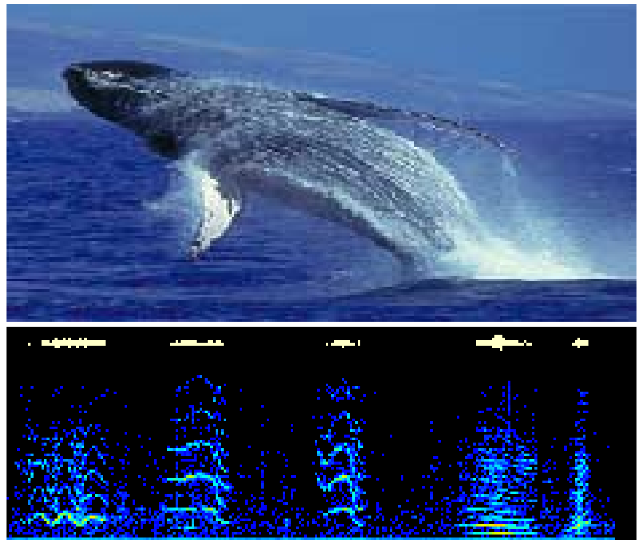


Figure II-15. Upper Panel: North Pacific Humpback Whale. Lower Panel: Segment of Humpback Song Recording Using Southern California SOSUS Arrays.

Pollution Prevention Accomplishments

Low-VOC Chemical Agent Resistant Coatings

Figure II-16. Current Camouflage CARC Painting at a DoD Depot Releases HAPs and VOCs to the Atmosphere.

Chemical warfare survivability dictates that virtually all Army and Marine Corps tactical equipment, and some Air Force support equipment, must be resistant to the effects of chemical agents. Chemical Agent Resistant Coatings, or CARC, accomplish this task. The coating currently employed is a solvent-based polyurethane having a VOC content of 3.5 pounds per gallon. At current production levels, 10.4 million pounds per year of VOCs are emitted to the atmosphere from CARC painting operations (Figure II-16). The Clean Air Act and its amendments have resulted in subsequent restrictions on the allowable amount of VOC emitted to the atmosphere and have classified many of the solvents used in the CARC system as hazardous air pollutants, or HAPs.

To respond to this issue, SERDP sponsored the **Low-VOC Chemical Agent Resistant Coating for Military Applications (PP-1056)** project. A multi-Service development team focused on developing two products: (1) a water-reducible, two-component polyurethane topcoat, implementing water-dispersible hydroxy-functional polyesters and water dispersible poly-iso-cyanates; and (2) a novel pigment system featuring the use of polymeric beads in lieu of siliceous extenders. These beads are largely responsible for a dramatic improvement in flexibility and mar resistance of the coating. The research team successfully used recent innovations in polymer science and pigmentation technology to develop a new water-reducible CARC topcoat formulation in which all HAPS were completely eliminated, and VOCs reduced in half from 3.5 lbs/gal to 1.8 lbs/gal. The Army Research Lab has drafted a new MILSPEC and has been awarded a U.S. Patent for their innovation. This new formulation has resulted in significant benefits to the Department of Defense, including:

- Annual VOC emissions will be reduced by approximately 5 million lbs;
- Compliance with current and proposed environmental regulations will be achieved without use of costly emission control equipment, such as scrubbers and afterburners;
- Physical properties of the new topcoat have been significantly improved and re-paint cycles will be extended due to the superior physical properties of the new topcoat;
- An estimated 25% increase in paint service life will result in an operational cost savings to DoD of $3 million annually and a capital equipment cost avoidance of $60 million.

This project was recognized and awarded the SERDP Pollution Prevention "Project of the Year" Award for FY 2000 at the Partners in Environmental Technology Technical Symposium and Workshop held November 28-30, 2000.

Next Generation Fire Suppression

Halon 1301 (CF_3Br) has long been the chemical of choice for fighting fires in military facilities and weapon systems. However, due to its high ozone-depletion potential, production of CF_3Br ceased in 1994. By 1997, DoD had found that the best commercially available replacements had serious weight and volume penalties that compromised implementation on existing weapon systems. Therefore, DoD initiated a national research program with SERDP to develop new fire suppressants for fielded weapon systems. The goal of the **Next Generation Fire Suppression Technology Program (NGP) (PP-1059)** is to demonstrate by 2005, technology for economically feasible, environmentally acceptable, user-safe processes, techniques, and fluids to meet the operational requirements formerly satisfied by halon 1301 systems in aircraft.

A major breakthrough for the NGP team, led by the National Institute of Standards and Technology (NIST), has been the development of a screen test that captures the realism of actual suppressant discharges in engine nacelles and dry bays. For the first time ever, compressed and solid-propellant-generated gases (SPGG) can be compared side-by-side, and the effect of different SPGG designs and formulations can be measured. As in real cases, the fire can be from a liquid fuel pool or spray. In a successful test, the agent must be present in the flame zone at a design concentration for a sufficient time to ensure that the flames are quenched and do not re-ignite. Figure II-17 demonstrates the value of this new apparatus and shows how all the different agents lie close to the theoretical equation regardless of whether the agent is chemically active or physically active or whether the agent is discharged from an SPGG or a compressed gas storage bottle. This test permits the accurate measurement of incremental improvements in performance which will greatly facilitate selection of the new

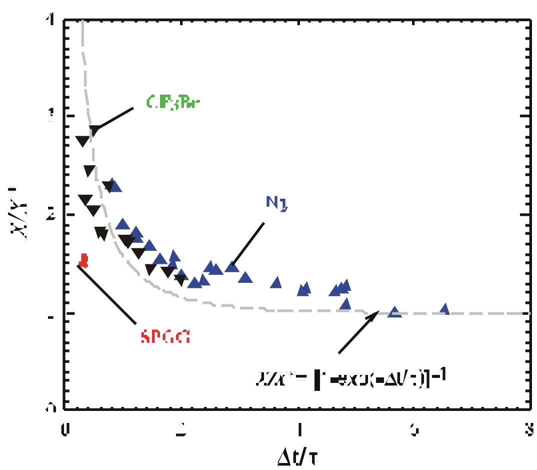


Figure II-17. Comparison of N_2, CF_3Br, and SPGG Effectiveness in the Transient Application, Recirculating Pool Fire Facility.

generation of fire supressants. In September 2000, NIST conducted a workshop to transfer the capability of this apparatus to suppressant and delivery hardware developers.

Green Energetic Materials

SERDP continues to invest in the development of pollution free energetic materials and munitions. The SERDP project entitled **Toxic Elimination from Small Caliber Ammunition (PP-1057)** developed substitutes and alternatives for hazardous materials used in the manufacturing of munitions and energetic materials. The U.S. Army Armaments Research, Development and Engineering Center (ARDEC) in Picatinny Arsenal, NJ, led the successful development of environmentally friendly tungsten-based projectile core materials to replace the current lead-antimony composition. This development has resulted in completing an Army goal to fully transition the production of 5.56mm, M855 ammunition to lead-free projectiles.

In FY 2000, this project continued work on the leachability, bio-uptake, and scale-up studies, and successfully completed the Metastable Intermolecular Composites (MIC) primer study. The majority of leaching studies are complete. Additional experiments involving the new bullet materials mixed with lead-containing bullets were added to explore possible interactions. Precision firing range tests were also conducted to determine reproducibility and accuracy of the projectile. Long-term leaching tests and biological uptake studies employing earthworms were completed and short and long-term exposures were conducted with similar results. The uptake of tungsten by plants was initially examined using bean plants and studies employing rye grass also were completed.

Metastable interstitial composites (MICs) were developed to replace lead styphnate-based primers, which also contain barium and antimony. MIC energetics were successfully demonstrated as an equal-to-baseline-velocity MIC material that meets operational extreme cold temperature (-65 °F) requirements, a key parameter that has eluded non-toxic primer research throughout the 1990s. However, since MIC is a heat generator only, its performance is reduced below that of propellant based primers. As a result, hybridization of the MIC material with gas spark generating compositions was explored and formulations were optimized to increase performance. The fabrication of the MIC constituents has been quantified through the development of characterization methods. In partnership with ARDEC, Indian Head Naval Surface Warfare Center, MD, and Los Alamos National Laboratory, NM, these methods have been successfully demonstrated and will improve manufacturability and yield as the process is scaled up. The successful establishment of a production process for a MIC material is crucial to a fully "greened" M855A1 cartridge.

Currently, solid rocket motor propellants use by DoD contain toxic/hazardous materials. Some propellants contain lead as a ballistic modifier that becomes an exhaust product during combustion. Other propellants contain ammonium perchlorate that produces hydrochloric acid (HCl) during combustion. Additionally, hazardous solvents must be used to process oxidizers. The SERDP project **Elimination of Toxic Materials and Solvents from Solid Propellant Components (PP-1058)**, has developed lead-free castable propellant formulations to meet the requirements for use in next generation tactical missiles.

Funded by SERDP in FY 2000, the U.S. Army Aviation and Missile Command, Aviation and Missiles Research, Development, and Engineering Center developed lead-free extrudable and castable propellant for minimum smoke systems. Two bismuth compounds were incorporated into high performance propellant formulations and were evaluated for processing, ballistic, mechanical, signature and aging properties. Acceptable test results were achieved in all evaluations. Propellant performance properties were at least equal to current formulations containing lead compounds and were superior to current state of the art formulations in some very important properties. Two of these lead-free propellants have been successfully tested in the TOW missile and 2.75" Rocket configurations (see Figure II-18).

Elimination of Hazardous Wastes and Emissions

DoD and DOE cleaning operations generate hazardous waste, wastewater, and solvent emissions, as well as consume energy, water, and production time. In many instances, parts are "over-cleaned" simply because it is difficult to quantitatively measure the degree of cleanliness. Cleaning performance verification procedures have been slow and expensive to develop because most available verification methods are not suitable for real-time measurement. In the **Visual Cleaning Performance Indicators for Cleaning Verification (PP-1117)** project, a research team led by Battelle Columbus has developed an operable in-line/on-line cleaning performance verification indicator (VCPI) technique that will accurately assess part cleanliness. The VCPI approach uses selective dyes/contaminant labeling chemistry and actual cleaning protocols to provide visual control of cleaning operations (Figure II-19). Field application targets included large area surfaces of aircraft and ships, cleanup for metallic, metallic-coated, and non-metallic surfaces, field cleaning and resurfacing, and includes a variety of contaminants. Key categories of contaminants included: (1) hydrophobic fluid (oils, greases, paint strippers, fuels, hydraulic fluid); (2) metal corrosion products; and (3) soluble corrosive salts especially chloride ion (sea water).

Figure II-18. Left: Anti-Solvent Process. Right: No-Lead 2.75" Missile on Test Stand. Bottom: Helicopter Firing 2.75" Rocket.

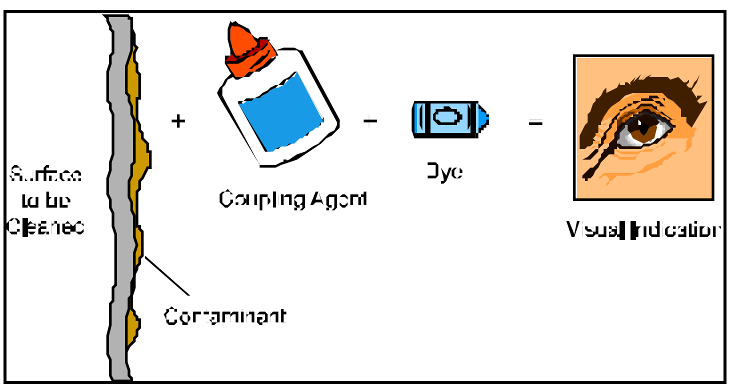


Figure II-19. VCPI Concept.

The VCPI process facilitates monitoring of the cleaning operation in real time allowing quick cursory evaluations of cleaning times, labeling times, solvents, aqueous cleaners, corrosion deposits, and contaminant uniformity. Initially, the target contaminants were identified for the specific cleaning operations. Commercially-available coupling agents and dyes that can attach to the target contaminants were then selected. Exploratory tests were then conducted on bulk contaminants and contaminated coupons were conducted to demonstrate the selective labeling of target contaminants. Based on laboratory-scale tests conducted in FY 2000, the VCPI technique has shown the potential to be valuable in helping to select cleaners and cleaning processes, both for large areas and complex parts. Detailed systematic cleaning tests to quantify these results will be used to rank the various DoD applications being tested.

Elimination of Chromium and Cadmium

The nonstainless ultrahigh-strength steels currently used for aircraft landing gear require toxic cadmium and hazardous chromium coatings to protect them from corrosion (Figure II-20). There has been a longstanding need to develop stainless, corrosion resistant steels with the same mechanical properties as landing gear steels so that the requirement for these coatings can be eliminated. Historically, the development of a new alloy could take 10 to 15 years. A SEED project entitled **Computational Design of Corrosion Resistant Steels for Structural Applications in Aircraft (PP-1149)**, led by QuesTek Innovations, has applied a revolutionary computational materials design approach developed by the Steel Research Group at Northwestern University under previous DoD support to greatly accelerate this process.

Figure II-20. Aircraft Landing Gear Require Hazardous Coatings to Resist Corrosion.

Science-based computational models were used to predict the evolution, during processing, of the multilevel microstructural parameters underlying the full range of properties necessary for the performance of a stainless landing gear steel. Novel design concepts included (a) exploitation of a Co-Cr thermodynamic interaction to achieve corrosion resistance with less alloy Cr content, (b) refinement of strengthening carbide particle dispersions to the same nanometer size scale as the protective oxide surface film to optimally combine strength and corrosion resistance, and (c) precise predictive control of structural transformation temperatures to achieve desired "martensitic" microstructures for high fracture toughness. The complete design and testing process took approximately 6 months and resulted in a single composition optimized to combine strength, toughness and resistance to corrosion, stress-corrosion and fatigue. Prototype evaluation with preliminary heat treatment optimization met most all primary property requirements and demonstrates performance superior to any composition evaluated in more than 100 prior steel industry empirical development efforts over the past 5 years. Refinement of design models indicates clear directions for further alloy improvement, and accelerated optimization and qualification of the new steel is proposed in FY 2001. It is expected that this research will result in a prototype of an entirely new corrosion-resistant steel that possesses similar mechanical properties to those of 300M and that will be compatible with current and emerging aerospace coating processes such as high-velocity oxygen fuel (HVOF).

III. PROGRAM DESCRIPTION

General

This section provides an overview of each of the SERDP Thrust Area Programs and planned initiatives for research. Topics include the goals of each Thrust Area, the environmental and operational drivers directing the needs for new and improved technologies, and the major areas of research and development (R&D) within each Thrust Area. Each FY 2000 and FY 2001 project is listed according to subthrust categorization and completion status.

The SERDP Program contains the following four Thrust Areas: Cleanup, Compliance, Conservation, and Pollution Prevention. Each year the Executive Director, with the assistance of the Executive Working Group (EWG) and the Scientific Advisory Board (SAB), determines the funding balance among these four Thrust Areas. Figure III-1 illustrates the distribution of funds to specific Thrust Areas for FY 2000 and FY 2001.

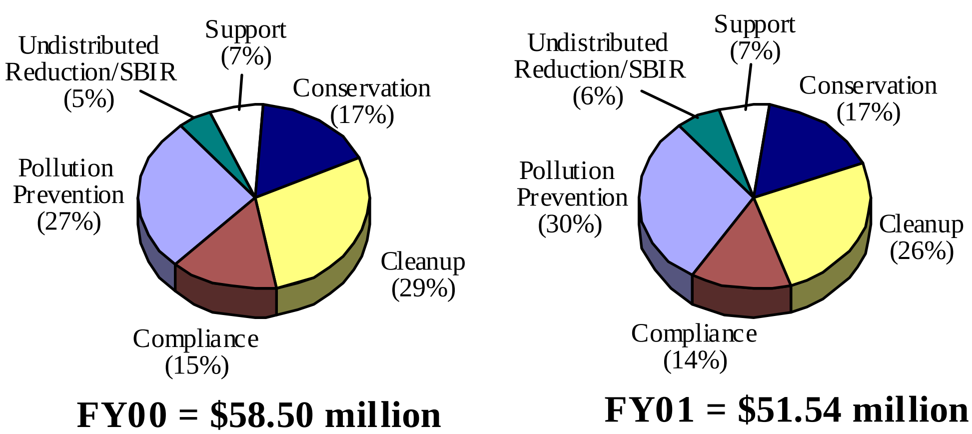


Figure III-1. Distribution of Total SERDP Funding, FY 2000 and FY 2001.
NOTE: FY00 values represent actual funding. FY01 values are planning figures based upon the President's Budget Request.

Program Development

SERDP PROJECTS	
FY 2000	
111	Total projects
39	Completed projects
38	New Start projects
FY 2001	
110	Total projects
36	Completing projects
38	New Start projects

SERDP funds environmental research and development through a competitive process in accordance with the established Congressional direction and is further guided by policies provided by the SERDP Council. There are two solicitations annually. One is the major, or core, solicitation and provides funding in various amounts for multi-year projects. The other is the SERDP Exploratory Development program, or SEED, program designed to provide initial funding for high-risk, high-payoff projects. SEED projects are limited to a one year time period and a maximum of $100,000 in funding.

Because both government and private sector parties may compete for SERDP funds, there are two announcements for each solicitation: (1) a Call For Proposals to the Federal sector and (2) a Broad Agency Announcement (BAA) for the private sector. In both of the FY 2001 Federal Call For Proposals, participating organizations and their laboratories were asked to solicit proposals that responded to the high-priority defense environmental needs as identified in the Statements of Need (SONs) which reflect the requirements developed by the Deputy Under Secretary of Defense for Environmental Security[DUSD(ES)]. Each Federal organization conducted its own internal down-select procedure and forwarded its best proposals to SERDP for consideration. The BAAs requested direct submission of proposals in response to the same DoD environmental needs from non-Federal participants from industry, non-profit entities, and academia. Both the core and SEED BAA solicitations appeared in the Commerce Business Daily.

Each year, a peer review panel is used in the core solicitation to assist in the down-select of Federal and non-Federal proposals. Following the peer reviewers' evaluation of technical merit and personnel, SERDP's multi-agency Technology Thrust Area Working Groups (TTAWG) were tasked with reviewing both the Federal and non-Federal submissions of both solicitations for all evaluation criteria. All proposals recommended by the TTAWGs and approved by the Executive Director were briefed to the SERDP SAB prior to recommending their approval to the SERDP Council. Titles of these projects may be found in the lists of FY 2001 New Start projects within each Thrust Area description subsection, and summaries of each new project are located in Appendices A through D.

CLEANUP

Introduction

The Department of Defense (DoD) and the Department of Energy (DOE) must protect human health and the environment, reduce remediation costs, and provide timely cleanup. Cleanup goals for the DoD are:

- To attend to imminent threats to public health and safety;
- To remediate all defense sites having a significant public health risk as quickly as feasible within the constraints of available resources; and
- To expedite transfer of base realignment and closure (BRAC) sites and formerly used defense sites (FUDS) to future owners.

The DoD and DOE have a legal obligation to meet Federal, state, and local environmental protection and public health regulations. Both organizations own and operate thousands of installations, ranging from training bases to industrial production facilities. DoD's environmental restoration program must address more than 27,000 sites at more than 8,500 installations. By the end of FY 1999, DoD had completed cleanup of approximately 62% of these sites and invested almost $21 billion in the environmental restoration program alone at active installations, formerly used defense sites (FUDS), and base realignment and closure (BRAC) installations.[1] Still, many significant challenges exist and must be addressed, including unexploded ordnance (UXO), Dense Non-Aqueous Phase Liquids (DNAPLs), as well as recently emerging issues such as MBTE, perchlorate, and energetic compounds in groundwater. Restoration funding levels over the past eight fiscal years have averaged more than $2 billion per year and are projected to continue at that level into the future. Commensurate R&D funding is necessary to ensure these challenges are met head on.

Experience with past remediation technology development has demonstrated a significant return on investment. Defense environmental managers require cost-effective and timely remediation capabilities that focus on assessment, characterization, and treatment. Each DoD Service has submitted its User Requirements for Cleanup, which are prioritized in the DoD Environmental Technology Requirements

[1] Fiscal Year 1999, Defense Environmental Restoration Program Annual Report to Congress.

Strategy (DETRS). These requirements can be categorized into specific environmental concerns. Within the Cleanup Technology Thrust Area, the primary environmental concerns are:

- Implement timely, effective, and affordable methods for site characterization, including detection and discrimination of UXO;
- Ensure the use of effective, affordable remediation technologies; and
- Comply with various Federal, state, and local regulations for site remediation.

These concerns are addressed by the Cleanup subthrusts and research areas as depicted in Figure III-2.

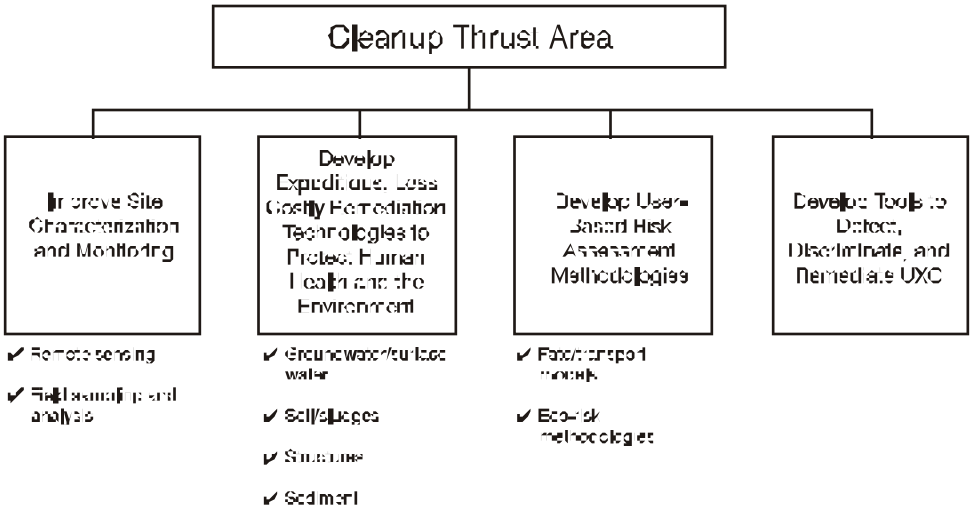
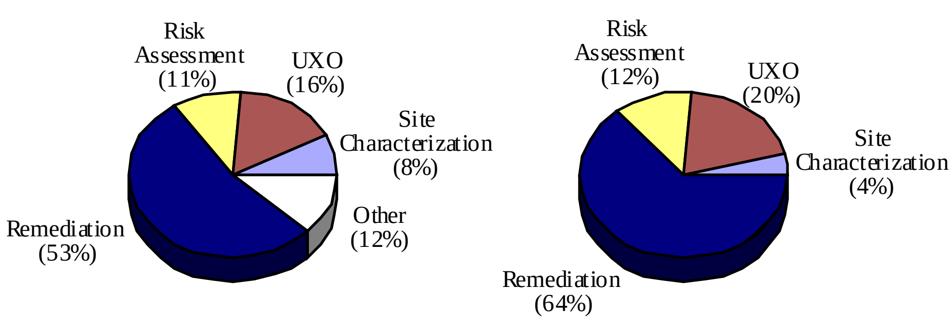


Figure III-2. Cleanup Taxonomy.

Figure III-3 shows the FY 2000 and FY 2001 Cleanup funding by subthrust area. For FY 2000, the Cleanup Technology Thrust Area received approximately 29 percent of the SERDP budget. While many defense cleanup situations will require that technologies be identified in the near-term, additional research in this area has the potential to provide the highest return on investment. Congress appropriated funds in FY 2000 specifically to conduct efforts investigating environmental toxicology. This project is represented under the "Other" category in Figure III-3.

CLEANUP	
FY 2000	
45	Total projects
17	Completed projects
18	New Start projects
FY 2001	
47	Total projects
17	Completing projects
21	New Start projects



FY00 = $17.10 million **FY01 = $13.40 million**

Figure III-3. SERDP Cleanup Funding by Subthrust, FY 2000 and FY 2001.
NOTE: FY00 values represent actual funding. FY01 values are planning figures based upon the President's Budget Request.

Principal Driving Requirements

The first subthrust area in Cleanup, **Improve Site Characterization and Monitoring**, seeks to develop better site investigation technology for locating and characterizing wastes. Identifying and characterizing sites contaminated with chlorinated solvents is a significant issue to the DoD. Chlorinated solvents represent a class of contaminants that are detected at more DoD sites than any other contaminant group. Chlorinated solvents, predominantly perchloroethylene and trichloroethylene, have been used in massive quantities over the last four decades. Release of these liquids to the environment accounts for a significant portion of the contaminated sites requiring cleanup. These contaminants have migrated through the subsurface and entered groundwater at more than 50 percent of the contaminated DoD sites. There is a comparable degree of contamination at DOE and private industry Superfund sites. Estimated annual costs exceed $500,000 for containing and monitoring a single, dense non-aqueous phase liquid (DNAPL) plume. Novel technologies to detect and characterize these plumes will significantly reduce these costs.

The second Cleanup Subthrust, **Develop Expeditious, Less Costly Remediation Technologies**, focuses on improved remediation of contamination in soils, groundwater, and sediments. Once contaminants reach the groundwater, they often are very mobile and can readily affect off-base receptors. Therefore, this subthrust is directed primarily at developing innovative technologies to address groundwater remediation more effectively. Current groundwater treatment strategies typically employ pump-and-treat technologies which are expensive to operate and are very slow to achieve lasting cleanup. Major limitations to the use of conventional pump-and-treat technology relate to difficulties in extracting contaminants from source areas where non-aqueous phase liquids (NAPLs) exist. In the area of energetic contamination, DoD is concerned with nitrated compounds that are widespread contaminants at DoD sites and have been identified at munition training ranges and production facilities. Over 700,000 cubic yards of soil and 10 billion gallons of groundwater require treatment at a cost estimated to be $2.66 billion. Trinitrotoulene (TNT) is the primary contaminant at these sites, along with dinitrotoluene (DNT), and other nitro substituted explosives (e.g., RDX and HMX). Current approaches used for site remediation typically involve excavation of contaminated soils, followed by incineration or composting, and pump and treat for contaminated groundwater. Because of past DoD and industrial activities, sediments at numerous sites also have some level of impact from anthropogenic (man made) compounds. The DoD must assess and manage contaminated sediments to conduct dredging, base closure, or to cleanup contaminated "hot spots." Remediation of contaminated sediments has proved to be very costly with current methods and environmentally risky. New and innovative technologies to treat and remediate contaminated sediments are needed to drive costs down and avoid potential impacts to surrounding areas.

The third subthrust area in Cleanup, **Develop User-Based Risk Assessment Methodologies**, involves identifying and evaluating the risk to the ecosystem at the 11,000 sites remaining on DoD installations potentially requiring environmental remediation.[2] These include: (1) distinguishing those sites that pose significant environmental risks from those that pose little risk; (2) prioritizing contaminated sites by the degree of risk posed; (3) quantifying the risks at each site; and (4) developing appropriate remedial actions and cleanup goals. Development of improved techniques for risk assessment, which provides a logical framework for making such decisions, is a DoD priority. The effectiveness of existing methods will be expanded by research directed at problems particularly evident at DoD installations.

The forth subthrust area in Cleanup, **Develop Tools to Detect, Discriminate, and Remediate UXO**, has been identified by the Services as the highest priority user need. It poses an enormous challenge to the effective cleanup of many DoD sites, primarily on land but also under water. Current estimates indicate that up to 11 million acres of land in the U.S. are suspected to contain UXO as a result of military training and weapons testing activities -- 6 million acres of UXO contaminated Army and Navy land, approximately 5

[2] Fiscal Year 1999, Defense Environmental Restoration Program Annual Report to Congress.

million acres on Department of Interior land, and at least 50 sites at sea. These lands represent the full range of terrains, vegetative cover, soil types, and geophysical characteristics. The present cost, driven largely by the need to exercise extreme safety precautions, ranges from $1,500 per acre for surface UXO to at least $5,000 per acre for sub-surface ordnance.

Leveraging with other defense science and technology programs and industry, the Cleanup Technology Thrust Area focuses on the following R&D objectives:

- Develop investigation methods and technologies that are capable of locating and characterizing wastes in a timely, cost effective, and quality manner;
- Develop innovative, compliant technologies that reduce remediation costs for sites containing explosives, propellants, petroleum hydrocarbons, solvents, heavy metals, and other organic/inorganic contaminants;
- Facilitate transfer of cleanup technologies to field use. This includes, but is not limited to encouraging the use of the National Environmental Technology Test Sites (NETTS);
- Develop cost-effective methods and tools to determine fate, transport, and effects of significant defense-related contaminants;
- Develop risk-based modeling and simulation methods for hazard assessment and establishing cleanup priorities and scientifically defensible cleanup levels;
- Develop scientifically defensible environmentally acceptable endpoints (EAEs) for DoD chemicals of concern, including chlorinated organics, explosive compounds, and heavy metals, to facilitate risk-based cleanups at DoD sites; and
- Develop reliable and cost effective means to identify, assess, and clean lands and underwater areas (inland, estuarian, and marine) contaminated with unexploded ordnance.

Cleanup Program

The following list reflects FY 2000 completed projects and projects continuing into FY 2001. Also included are titles of projects that begin in FY 2001. Complete descriptions of all of the projects for FY 2000 and FY 2001 may be found in Appendix A - Cleanup Project Summaries.

Subthrust: *Improve Site Characterization and Monitoring* **Page**

Subthrust: *Develop Expeditious, Less Costly Remediation Technology*

FY 2000 Completed Projects

FY 2001 Continuing Projects

FY 2001 New Start Projects

Subthrust: *Develop Risk Assessment Methodologies*

FY 2000 Completed Projects

FY 2001 Continuing Projects

FY 2001 New Start Projects

Subthrust: *Detection, Discrimination, and Remediation of UXO*

FY 2000 Completed Projects

FY 2001 Continuing Projects

FY 2002 Cleanup Initiatives

Detection and discrimination of UXO continues to be a major research priority in the Cleanup Thrust Area. To this end, a FY 2002 Statement of Need (SON), **UXO Site Characterization and Remediation Alternatives for Highly Contaminated Sites**, has been issued. Through this SON, SERDP looks to fund development of technologies to support clearance actions for unexploded ordnance found on highly contaminated sites. The research and development would focus on one or more of the following activities: (1) improved signal processing and/or sensors to aid in discrimination clutter from targets in contaminated areas where overlapping signatures are common; (2) mechanical or other methods to aid in the cost effective and safe direct clearance of highly contaminated sites; and/or, (3) analytic work and supporting technologies to aid in the decision process for determining the appropriate clearance action or combination of clearance options. Modern geophysical surveying techniques can be effectively used to characterize sites potentially contaminated with UXO. For sites where signatures are sparse and anomalies are spatially isolated, these tools can guide detection-driven remediation activities and in some cases can effectively screen clutter from ordnance. However, many sites contain highly contaminated areas such as target bull's-eyes, where geophysical signatures from sub-surface anomalies overlap. In these cases, methods of discrimination have not been adequately developed and demonstrated.

Another UXO-related proposed area of new research is entitled **UXO Site Characterization for Large Areas of Rough or Vegetated Terrain**. The purpose of this SON is to solicit proposals to develop sensors, processing approaches and/or innovative platforms, which will provide a new capability to cost effectively characterize large sites (1000s of acres) suspected to be contaminated with UXO. The approaches proposed must be applicable to rough and/or vegetated terrain. Standoff systems are required that would allow detection of ordnance and ordnance like objects reliably enough to distinguish contaminated from uncontaminated regions. The footprint required for detailed geophysical surveys can be reduced if the processed information from standoff systems can distinguish, with high confidence, approximate boundaries of contamination within larger sites. It is also desired to develop standoff systems that would provide sufficient information to allow for remediation decisions regarding individual detected geophysical anomalies. Current airborne technologies (helicopter based magnetometry) that provide the capability to characterize open flat terrain where sensors may be flown at very low altitudes (2 meters) have been developed and are currently being demonstrated. The objective of this SON is to develop systems with significantly enhanced capabilities over these existing systems.

Another proposed new initiative is focused on and entitled **Improved Understanding of In Situ Chemical Oxidation (ISCO)**. The purpose of this SON is to develop an understanding of: (1) the mode of action of oxidants on free phase and residual dense nonaqueous phase liquids (DNAPLs), including the associated chemical reactions, reaction kinetics, and other effects that can impact overall destruction efficiency; (2) the stability and reactivity of oxidants in an aquifer matrix with varying soil conditions (pH, iron content, etc.); and (3) the impact of varying soil parameters on oxidant fate and overall destruction efficiency. Results from these efforts should lead to: (1) an improved understanding of the potential of in situ chemical oxidation (ISCO) for the destruction of DNAPLs; (2) identification of the limitations associated with ISCO; and (3) development of improved application methodologies.

The last core FY 2002 proposed area of new research will investigate **Impacts of Source Zone Treatment**. The purpose of this SON is to develop an increased understanding and characterization tools to better assess the need for and impacts of source zone treatment technologies. Specifically, this SON seeks fundamental or applied studies that will result in or lead to assessment tools or approaches to evaluate the site specific appropriateness of DNAPL source zone removal/destruction technologies and/or an ability to predict the effect of source zone removal/destruction on the dissolved phase plume. This SON seeks an improved understanding of the costs and benefits of technologies designed to remove or destroy residual sources of chlorinated solvents in the subsurface.

In addition to the core SONs discussed above, SERDP has solicited proposals in response to three Cleanup/UXO SEED SON topics. Through the first SEED SON, SERDP intends to fund research seeking **Alternatives to Microbial Microcosm Studies** in order to develop alternatives to the current practice of utilizing microbial microcosm studies to support the selection, design, operation and monitoring of bioremediation strategies. This SON will explore the proof-of-concept for technologies that will minimize the time required to make engineering judgments related to the probability of successful implementation of bioremediation on a site specific basis.

The second FY 2002 SEED SON solicitation intends to fund research seeking **Alternative Technologies for Long Term Monitoring**. The purpose of this SON is to solicit proposals to develop technologies that can be implemented to reduce the financial, personnel, and technical resources necessary for long term monitoring of sites undergoing restoration. The proposed work should focus on proof-of-concept for developing innovative engineered hardware/systems for quantifying chemical contaminants in complex environmental settings.

The third FY 2002 SEED SON solicitation intends to fund research in pursuit of **Innovative Approaches to UXO Cleanup**. These SEED projects should seek to develop proof of principle for new sensors, explore new discrimination techniques, or illustrate new render-safe or removal technologies, or technologies that support such efforts through improvements in navigation, geo-location, or ground or airborne vehicle technologies. Advances are needed in all aspects of the procedures for the detection, discrimination and rendering safe of UXO. Items ranging from 20-mm shells to 2000-lb bombs must be detected and discriminated from other non-hazardous items in the subsurface. Algorithms are needed that can exploit data from current state of the art sensors and advanced sensors that are now becoming available. This must be done in a variety of environments, using a variety of supporting vehicle and navigation technologies.

Detailed descriptions of the FY 2002 Cleanup Statements of Need may be found in Appendix E.

COMPLIANCE

Introduction

In the United States, the DoD must comply with Federal environmental protection laws such as the Clean Water Act (CWA), the Clean Air Act and Amendments (CAAA), and the Resource Conservation and Recovery Act (RCRA), as well as state and local regulations. These laws result in specific requirements for the treatment of emissions and disposal of wastes generated during DoD operations, including those generated by vehicles, aircrafts, and vessels, as well as from training exercises involving the firing of munitions. At the international level, the International Maritime Organization's Marine Pollution Convention (MARPOL) Annexes (to which the United States subscribes) may restrict or prohibit DoD operations in international waters and MARPOL Special Areas unless vessels meet international environmental statutes. In addition, countries that host DoD facilities are implementing and enforcing compliance with regulations and standards that may restrict or prohibit DoD operations in foreign ports and bases.

Together, these requirements affect numerous defense activities and assets both at home and abroad, including combat testing and training; operational installations; ordnance and weapons manufacturing and disposal; and combat vehicles, ships, and aircraft operations. As a result, DoD is projected to spend between \$2 and \$3 billion annually for environmental compliance, requiring monitoring and treatment of emissions and wastes generated by military operations and training. New technologies must be developed to reduce this cost and enable the DoD to comply fully with increasingly stringent requirements while fulfilling its mission unencumbered by regulatory fines, restricted access or mobility, or negative public reactions. In addition, full compliance with environmental regulations is a critical step in DoD's initiative to achieving and maintaining sustainability.

Therefore, the mission of the Compliance Technology Thrust Area in SERDP is to research and develop new technologies to:

1. Address current and future environmental compliance requirements of the DoD and Department of Energy while maintaining military readiness, and

2. Reduce the costs associated with these requirements.

Compliance technologies are not to be directly related to site restoration but are related to meeting current and future environmental compliance requirements of DoD and DOE. They include end-of-pipe recycling (i.e., waste that is reused for other than its original purpose). Further, they address understanding the fate and transport of defense-related air and wastewater discharges. These technologies do not include elimination of waste streams through substitution or process modification which are included in the Pollution Prevention Thrust Area.

The primary concerns in this technology thrust area include deterioration or loss of operational capability and the high costs of regulatory compliance. Each of the uniformed Services has submitted its User Requirements for Compliance, which are based on existing environmental protection laws and prioritized in the DoD Environmental Technology Requirements Strategy (DETRS). These primary DoD environmental concerns reflect the need to:

- Better characterize wastes though improved measuring/monitoring technologies;

- Develop effective treatment/recycling technologies for defense wastes and/or emissions; and

- Develop improved fate and transport prediction capabilities for emissions and/or discharges of specific compounds or contaminants.

Each of these User Requirements respond to specific environmental regulations that have been developed under the CAAA, the CWA and amendments, and, for solid and hazardous wastes, the RCRA. Given the compliance requirements that result from these three major laws and their amendments, as well as related standards, SERDP addresses Compliance according to five major subthrust areas related to affected environmental media as shown in Figure III-4.

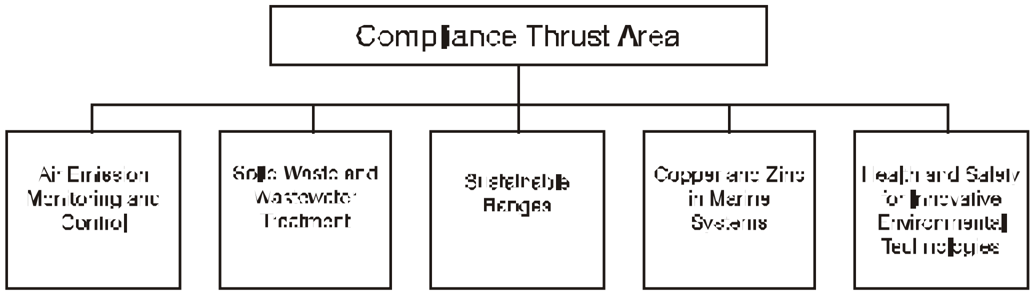


Figure III-4. Compliance Taxonomy.

Figure III-5 shows Compliance funding by subthrust area for FY 2000 and FY 2001. For FY 2000, Compliance received approximately 15 percent of the total SERDP budget. A slight decrease in SERDP's Compliance Technology Thrust Area investment is anticipated over the next five years, although this could change with the implementation of new environmental regulations. Congress appropriated funds in FY 2000 specifically to conduct efforts in support of health and safety training aspects related to persons undertaking remediation work, including the scrapping of Navy ships. This project is represented under the Health and Safety or "H&S" category in Figure III-5.

COMPLIANCE

FY 2000	
20	Total projects
9	Completed projects
6	New Start projects

FY 2001	
18	Total projects
7	Completing projects
7	New Start projects

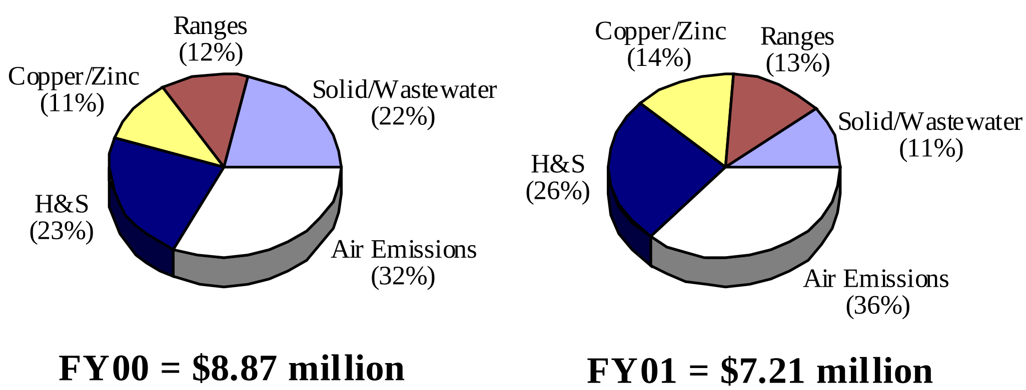


Figure III-5. SERDP Compliance Funding by Subthrust, FY 2000 and FY 2001.
NOTE: FY00 values represent actual funding. FY01 values are planning figures based upon the President's Budget Request.

Principal Driving Requirements

For FY 2000, SERDP responded to requirements resulting from specific regulatory developments within five Compliance subthrusts. For the **Air Emissions Monitoring and Control** subthrust, DoD must develop new and effective measuring/monitoring and treatment/control technologies for air emissions resulting from DoD activities. In the course of implementing the CAAA of 1990, a number of local air quality jurisdictions (many facing non-attainment status for one or more priority pollutants) have imposed local standards that are more stringent than national emissions standards. The employment of military-unique systems such as liquid-fuel rockets, military jet engines, and mobility equipment will require that DoD treat and control emissions of NOx, ultrafine particulate matter (PM), volatile organic compounds (VOC), and hazardous air pollutants (HAP) at DoD installations. One difficulty associated with monitoring and controlling these emissions is that they frequently are episodic or high-volume and low-concentration, such as jet engine test cells, painting, stripping, and cleaning operations. Existing CAAA regulations and anticipated future restrictions on NOx, ultrafine PM, VOCs, and HAPs are testing the limits of existing emissions monitoring and control technology which in some cases does not meet portability or detection limit requirements. Without new technology, the curtailment of missions, closing of facilities, and assessment of fines are real possibilities.

Within the **Sustainable Ranges** subthrust, research and development is a key element to managing military ranges as a sustainable resource. This subthrust focuses on developing techniques to assess the potential for environmental impacts of residual energetic materials that may be found at military ranges as a result of the use of munitions. The research conducted under this subthrust is intended to contribute to the DoD's capacity to: (1) understand range environmental issues; (2) improve management of these critical resources; (3) assure the long-term viability of these key assets; and (4) facilitate compliance with current and proposed regulations. It supports the 1996 Defense Science Board (DSB) Report and Environmental Security Plan for test and training range sustainment. Also within this subthrust, the disposal of the huge stockpile of munitions and propellants by open burning/open detonation (OB/OD) has raised concerns about the impacts of OB/OD activities on the health of humans and ecosystems, severely restricting and sometimes prohibiting, OB/OD. While FY98 was the last year that SERDP initiated R&D in this area as a result of the establishment of the DoD Conventional Munitions Demilitarization Office, one project in this area was completed in FY 2000.

For the **Solid Waste and Wastewater Treatment** subthrust, DoD must meet international environmental regulations limiting the disposal of solid waste and plastics at sea. To address this need, the Navy must develop compact, efficient equipment for the destruction of solid waste and sludges from waste water onboard DoD vessels. The CWA requirements also prohibit the discharge of untreated sewage (blackwater) by ships in navigable waters. Shipboard graywater is the product of hotel and commissary-type activities aboard U.S. Navy ships. Common sources of graywater are showers, sinks, and galley and scullery equipment. No graywater holding capacity has been required for U.S. Navy ships with the exception of operations within the Great Lakes. However, with anticipated tightening of global wastewater discharge regulations, DoD must develop technologies that are appropriate to control and treat combined shipboard graywater and blackwater (i.e., non-oily wastewater).

For the **Copper and Zinc in Marine Systems** subthrust, DoD must advance the current scientific knowledge of the fate and impact of copper and zinc from DoD sources in harbors and estuaries in order to develop a scientific basis for future approaches to copper and zinc regulations. Copper and zinc are two of the most ubiquitous contaminants found in many industrial and non-point source effluent, including discharges from DoD facilities, ships, and small craft into the marine environment and sediments disrupted during dredging operations. DoD sources of copper include storm waters, point sources, hull coatings, and discharges from DoD ships and facilities. Studies have shown that copper and zinc are highly toxic to some marine organisms. Copper and zinc discharges often exceed existing water quality criteria (WQC) or standards in the effluent and copper often exceeds WQC in the receiving systems. DoD needs to provide risk assessments that can be correlated to the sources of copper and zinc discharging into, or present in, harbors and/or estuaries and thereby regulate these sources to acceptable levels in a technologically feasible and cost effective manner. Examining the fate and impact of these metals has the long-term benefit of providing scientific evidence to support the development of more realistic water quality criteria and standards. These efforts could drastically reduce the costs associated with the treatment and/or mitigation of copper and zinc to current compliance levels by providing scientifically supported information as to the presence of the metals in the environment.

For the **Health and Safety for Innovative Environmental Technologies** subthrust, DoD is working to improve the health and safety of workers and communities involved in environmental remediation. Improvements in the training of workers and the delivery of useful information to communities affected by remediation are critical aspects. DoD is seeking to develop efficient means to include health and safety information in the documentation which accompanies these technologies to the field. This can be accomplished by including health and safety information as part of the design considerations and by systematically developing health and safety information that can accompany new technologies to the pilot or deployment stage. SERDP funded one project in this subthrust in FY 2000 to contribute both new technology and health and safety input to the problem of U.S. Navy ship disposal. This project will document the baseline methods for the process, which will allow rational improvements to be proposed.

For FY 2000, SERDP supported a total of 20 Compliance projects. Eight of these projects address air emissions, reflecting the emphasis to respond to existing clean air regulations and the anticipated CAAA requirements for VOCs, NOx, dust, and PM less than 2.5 microns in diameter. Of the 8 projects in the Air Emissions Monitoring and Control subthrust, 6 are developing emissions treatment/reduction technologies and 2 are developing measuring and monitoring technologies. Of the 4 projects in the Copper and Zinc in Marine Systems subthrust, one is developing a simple to use ion probe to monitor copper levels in water and 3 are evaluating the fate and transport of copper and zinc in the water column and in the sediments in estuarine environments. Of the 3 projects in the Sustainable Ranges subthrust, one is developing technology to safely destroy energetic materials and 2 are evaluating the fate and transport of energetic materials in soil and in air. Of the 4 projects in the Solid Waste and Wastewater Treatment subthrust, 3 are developing chemical and biological treatment and filtration processes to treat shipboard wastewater and one is developing an advanced incinerator to treat shipboard sludges. One Congressionally directed project in the Health and Safety for Innovative Environmental Technologies subthrust is assessing environmentally sound technologies for the scrapping of Navy ships.

The EPA is proposing the Regional Haze Rule and Toxics Release Inventory (TRI) reporting requirements for munitions. These proposed regulations require new and innovative technologies to monitor and characterize emissions of dust from testing and training activities as well as emissions of TRI chemicals from munitions firing. On a related issue, DoD needs to dispose of an increasing amount of metal scrap material produced by testing and training activities that use munitions and other energetic materials. These scrap materials may contain energetics residues that could pose a hazard for the recycling of this metal scrap. During FY 2000, the SERDP Compliance Thrust Area solicited proposals and approved FY 2001 New Start projects that will focus on (1) dust emissions at testing training ranges, (2) emissions of TRI chemicals from the use of munitions, and (3) treatment of energetics residue on range scrap.

Three new start projects were selected for funding in FY 2001 to address dust emission monitoring needs. Two of these projects will focus on new monitoring technologies to characterize fine particulate and dust emissions from training activities at military installations in the arid west and one project will develop a GIS-based terrain model of atmospheric dust emissions. Two projects will be funded in FY 2001 to address the need to characterize TRI emissions from the firing of munitions. Of these two project, one project will perform fundamental studies of these air emissions and the other will conduct a field monitoring program to identify TRI chemical emissions and develop emissions factors for munitions activities. Two SEED projects will be funded in FY 2001 to (1) evaluate novel technologies to detect energetics residues on range scrap materials, and (2) develop methods to remove, treat, or recover energetics residues on range scrap.

Compliance Program

The following list reflects FY 2000 completed projects and projects continuing into FY 2001. Also included are titles of projects that begin in FY 2001. Complete descriptions of all of the projects for FY 2000 and FY 2001 may be found on the pages referenced in Appendix B - Compliance Project Summaries.

Subthrust: *Air Emissions Monitoring and Control* — Page

Subthrust: *Solid Waste and Wastewater Treatment*

FY 2001 New Start Projects

None

Subthrust: *Sustainable Ranges*

FY 2000 Completed Projects

FY 2001 Continuing Projects

FY 2001 New Start Projects

Subthrust: *Copper and Zinc in Marine Systems*

FY 2000 Completed Projects

FY 2001 Continuing Projects

FY 2001 New Start Projects

None

Subthrust: *Health and Safety for Innovative Environmental Technologies*

FY 2000 Completed Projects

FY 2002 Compliance Initiatives

FY 2002 Compliance Initiatives will respond to recently finalized as well as anticipated regulatory developments related to DoD air emissions, non-point source runoff to surface waters from DoD lands, and clearing of range residue and scrap from testing and training activities on DoD installations.

Under the CAA Amendments of 1990, EPA is required to regulate emissions of 188 listed air toxics. EPA is currently conducting a National-Scale Air Toxics Assessment that, when complete, will include 33 air toxics that present the greatest threat to public health in the largest number of urban areas. Under EPA's national Urban Air Toxics (UAT) Strategy program, EPA will develop a strategy to identify and address risks to the public in urban areas via development of national standards for stationary and mobile sources to improve air quality. The UAT Strategy complements existing efforts by focusing on actions to reduce emissions of air toxics and specifies assessment activities to improve understanding of health and environmental risks posed by air toxins in urban areas. To proactively respond to these developments, SERDP has issued an SON for FY 2002 entitled **Source and Ambient Air Toxic Monitoring for DoD Operations**. The focus of this SON is to identify and characterize emissions of trace air toxic compounds, especially persistent organic pollutants, from operations/activities at DoD facilities. The sources and modes of operations that lead to such air toxics via sensitive instruments should also be identified and characterized. Technologies need to be developed to perform measurements in near real time and at a high temporal rate. Emissions factors will be developed for those compounds that are characterized.

A second SON was issued for FY 2002 to respond to a need to estimate the impact of DoD air emissions on air quality at a regional scale. Many DoD facilities are located in, and operations are conducted in, environments such as complex coastal zones where atmospheric, oceanic, and hydrological processes dominate the transport, transformation, and dilution of pollutants. Similarly, other relevant environments range from humid, forested landscapes to high, arid mountainous domains. In addition, DoD operations span the range of ordinary emissions such as from vehicles, aviation, and marine operations to unique operational emissions. The environment into which these emissions emerge also varies on the time scales of hours to seasons to years, all of which need to be accommodated in an observation and prediction system that in turn depends on an optimal mix of observations. The objective of research under the SON **Observing and Predicting the Emission Rates, Transport, Transformation, and Fate of Air Pollutants Associated with DoD Activities Worldwide** will be to provide an improved observational and predictive ability of the impact of air pollutants emitted from military facilities and operations on local and regional air quality. The objective of research under this SON is to exploit existing monitoring techniques and observation systems and adapt existing atmospheric chemistry and meteorological models.

Amendments to the Clean Water Act and the Uniform National Discharge Standards were identified as important drivers for formulating a third core SON for FY 2002, **Aquatic Invasive Species**. The objective of this SON is to solicit proposals to develop a better understanding of the role DoD operations play in the introduction of non-indigenous aquatic species that can be used as a guide to the development of new technologies aimed at controlling these introductions. Proposals are being solicited to: (1) quantify the abundance and diversity of organisms in the ballast water of DoD vessels; (2) quantify the abundance and diversity of organisms occurring as hull fouling on DoD vessels; (3) survey a variety of vessels operating on both coasts and on inland waterways; and (4) relate findings as to organism abundance and diversity to operational histories, maintenance histories, and any management practices carried out by crews that may affect the occurrence of non-indigenous species in or on a vessel.

Detailed descriptions of the FY 2002 Compliance SONs may be found in Appendix E.

CONSERVATION

Introduction

DoD is a major user of land, sea, and air, and manages approximately 25 million acres of land on more than 425 major military installations. It is the third largest Federal land management department in the United States. DoD requires continued access to these lands, waterways, and airspace to maintain mission readiness. Land is needed for munitions testing, deployment of weapon systems, and combat training exercises. Marine and estuarine environments are needed to conduct training exercises, test vessels and submarine tracking equipment, evaluate missile weapon systems, and conduct shock trials on new ships. Airspace is needed to train pilots and test fighter planes and air-based weapon systems. The specific landscapes and unique natural features of the land, sea, and air space used by DoD are crucial to maintaining military readiness. Varied training regimens and differing climatic, topographic, hydrologic, and biological settings prepare troops to operate equipment and carry out operational plans under conditions that they may encounter in future conflicts. With a broad geographic distribution (largely domestic but some foreign), DoD lands represent a remarkably diverse collection of ecosystem and habitat types, including forests, grasslands, wetlands, and deserts. DoD's ability to conduct realistic training exercises and to test weapon systems and equipment cannot be ensured without responsible land stewardship and sensible management and conservation practices.

DoD must maintain the nation's natural and cultural resources of the installations upon which it depends. It also must comply with legislation and regulations designed to protect these resources. By better understanding the environments in which they operate, the Department can improve its resource-use decisions to promote conservation and stewardship, while continuing to fulfill their primary missions. The DoD Conservation goal is to support the military mission by: (1) providing for sustained use of its land, sea, and air resources; (2) protecting valuable natural and cultural resources for future generations; (3) meeting all legal requirements; and (4) promoting compatible multiple uses of those resources.

Furthermore, military facilities face increasing demands as a result of base closures and realignments, new weapon systems and equipment requiring larger training ranges, additional regulatory constraints, and changes in tactics and doctrine. Training intensity on remaining installations will continue to rise, often preventing full recovery of vegetation and animal populations between training exercises. The U.S. Army alone has 11 million acres of training and testing lands with land repair and maintenance costs of $56 million annually. On-site and off-site environmental impacts, wildlife conservation issues, cultural resources concerns, and the need for training realism all dictate that natural resources must be maintained and enhanced on these installations. The tasks of balancing military land uses, complying with resource regulations, and assessing impacts on the sustainability of both the resource base and the military mission are complex and challenging. Activities to alleviate one problem can often exacerbate others. All too often, decision-makers on military installations are faced with making critical land management decisions without the benefit of complete environmental information nor complete knowledge of other, competing objectives and/or land use requirements.

Leveraging with other Defense science and technology programs and similar programs in industry and academia, SERDP focuses on the following Conservation research and development objectives to support DoD's Conservation goals:

- Develop standardized, cost effective methods to inventory, characterize, and monitor natural and cultural resources to help ensure compliance with applicable laws and requirements. Where appropriate, use defense-unique data collection and assessment tools to develop these methods;

- Develop and demonstrate more effective methods and techniques to maximize availability of military lands in support of military missions, with minimal impact to natural and cultural resources in a manner consistent with the Services' mission and Federal environmental regulations;

- Develop and demonstrate efficient and effective techniques to conserve and restore natural and cultural resources proactively, particularly threatened and endangered species and the ecosystems on which they depend;

- Develop and demonstrate effective, user-friendly computer-based models to determine the incremental and cumulative impact of military activities on natural and cultural resources, and assess effectiveness of conservation and restoration techniques;

- Develop state-of-the-art techniques to assess and predict the impact of military use on those critical elements of the ecosystem impacting biodiversity; and

- Develop the needed methods, tools, guidelines, and decision support systems for effectively implementing integrated resource management techniques.

These research and development objectives are addressed and implemented under five related but distinct subthrusts which makes up the Conservation Taxonomy (as depicted in Figure III-6). Current focus areas or critical paths to DoD conservation goals are listed under each subthrust. These focus areas may change from year to year in order for the subthrust to appropriately adapt to new DoD requirements.

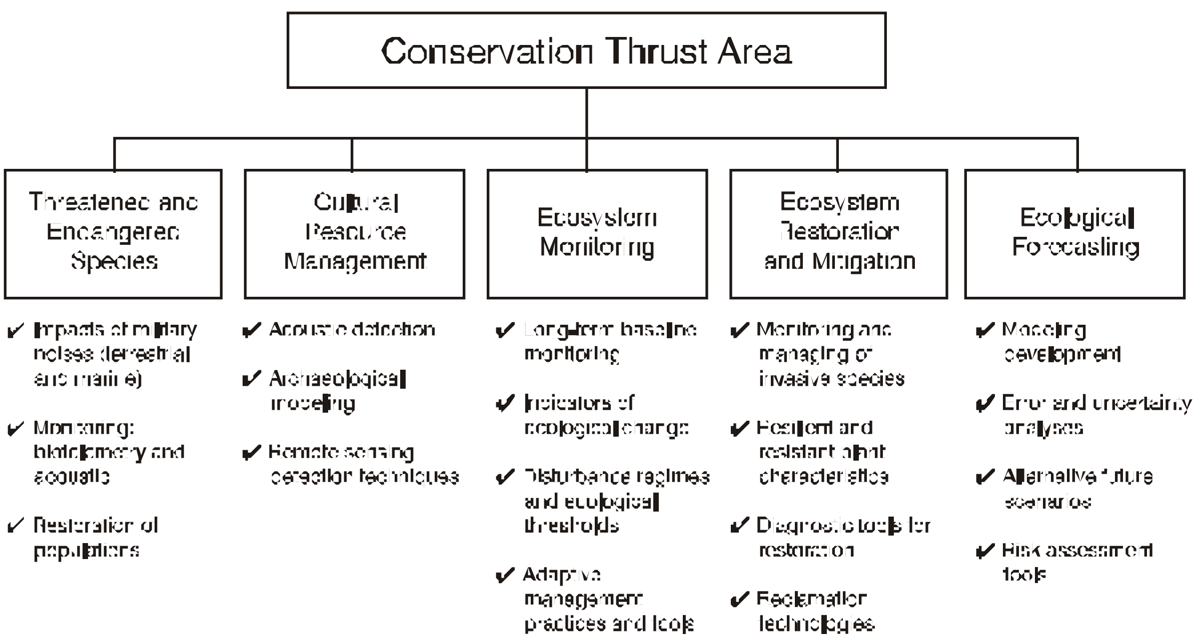


Figure III-6. Conservation Taxonomy.

CONSERVATION	
FY 2000	
21	Total projects
8	Completed projects
8	New Start projects
FY 2001	
18	Total projects
7	Completing projects
4	New Start projects

Figure III-7 shows the funding by subthrust area. For FY 2000, Conservation received approximately 14 percent of the SERDP budget. In future years, Conservation funding will gradually increase as a percentage of the SERDP funding to support a more sustainable future.

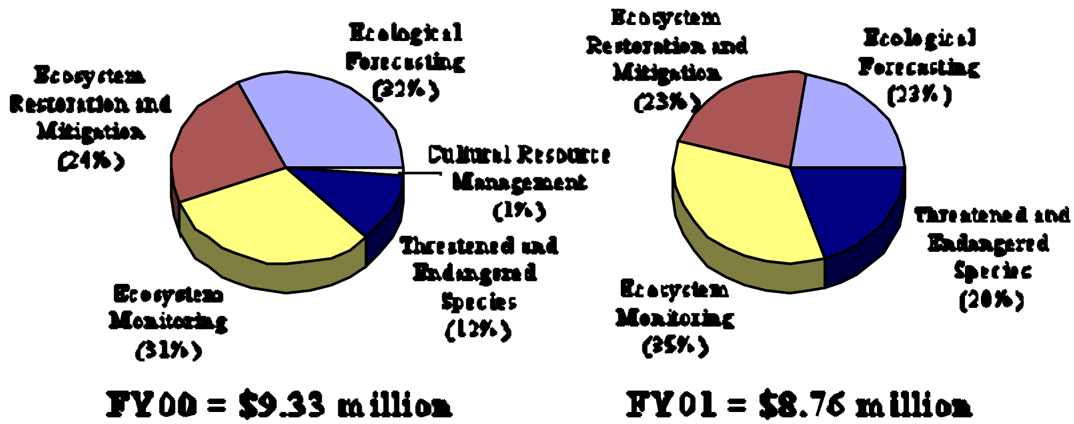


Figure III-7. SERDP Conservation Funding by Subthrust, FY 2000 and FY 2001.
NOTE: FY00 values represent actual funding. FY01 values are planning figures based upon the President's Budget Request.

Principal Driving Requirements

Each uniformed Service has submitted its User Requirements for Conservation, which are prioritized in the DoD Environmental Technology Requirements Strategy (DETRS). These individual requirements affect all operating environments and are addressed in the five related but distinct research subthrusts for Conservation.

DoD manages species of concern, and specifically Threatened and Endangered Species, to comply with the same laws and statutory provisions as all other Federal Agencies, including: Endangered Species Act (ESA) of 1973 (Section 1531 et seg. of title 16, United States Code); the Marine Mammal Protection Act of 1972 (Sections 1361 to 1421h of title 16, United States Code); and the Migratory Bird Treaty Act (Section 703 et seq. of title 16, United States Code). In addition, the following legal authorities apply specifically to the management of Threatened and Endangered Species on DoD owned or managed lands: "Conservation Programs on Military Installations (Sikes Act)," (Section 670 et seg, of title 16, United States Code); "Timber Sales on Military Lands," (Section 2665 of title 10, United States Code); "Outleasing for Grazing and Agriculture on Military Lands," (Section 2667(d) of title 10, United States Code); "Hunting, Fishing and Trapping on Military Lands," (Section 2671 of title 10, United States Code); National Environmental Policy Act (42 USC 4321-4370d); and Fish and Wildlife Coordination Act (16 USC 661-667d). The **Threatened, Endangered, and Sensitive Species** subthrust addresses DoD specific requirements that pertain to those species that are identified as either threatened or endangered (both currently and potentially). It is known that more than 200 installations provide habitat for at least 400 plants and animals that are listed on or candidates for the Federal endangered species list. This is the highest known density of threatened and endangered species found on any Federal lands. Research and development must be responsive and as proactive as possible in meeting all DoD requirements pertaining to these plants and animals.

The research and development focus for the Threatened, Endangered, and Sensitive Species subthrust has included the effects of aircraft overfights on birds of prey, biotelemetry, marine mammal responses to low frequency noise, whale monitoring, training noise impacts on the Red-Cockaded Woodpecker, salmon in the Pacific Northwest, and acoustic monitoring of Threatened and Endangered Species in inaccessible areas. The challenge for the Threatened, Endangered, and Sensitive Species subthrust will be to integrate the approaches and findings of research and development pertaining to specific species into the context of an ecosystem management approach. DoD recognizes that a species-by-species approach to resource management is potentially inefficient and can lead to contradictory management strategies. DoD has adopted an ecosystem approach to managing its natural resources. This approach considers groups of plant and animal species, instead of focusing on single-species management. It promotes adaptive management, the use of benchmarks and the best available science, and sustainable use for both human and ecological purposes. One way of doing this will be to integrate regional management strategies more effectively by reducing conflicting individual approaches. Working within an eco-regional context can help protect the viability of resident populations and reduce the likelihood of future listing of species under the ESA.

DoD lands contain more than 100,000 archaeological sites, and at least 200 installations have properties that are listed on or eligible for the National Register of Historic Places. Approximately two percent of all the military's buildings and structures are considered historic. Management of cultural resources on the many and varied military installations in the United States is necessitated by respect and by public laws that include but are not limited to the National Historic Preservation Act of 1966 as amended, (P.L. 89-665;16 USC 470 et seq.) the Archaeological Resources Protection Act of 1979 as amended (P.L. 96-95: 16 USC 470 et seq.) and the Native American Graves Protection and Repatriation Act of 1990 (P.L. 101-601:25 USC 30015 USC §3001 et seq.). The Cultural Resource Management subthrust addresses the research and development needs associated with the detection, sampling, and preservation of cultural resources on DoD installations. The R&D focus for the **Cultural Resource Management** subthrust has included acoustic detection, archaeological modeling, and remote sensing detection techniques. As a result of a co-sponsored SERDP/Legacy Cultural Resource Management workshop in June of 2000, a number of new research and development initiatives were identified in the categories of detection, preservation and data management. The reduction of cost and increase in efficiency are key drivers for defining the research and development investments in the Cultural Resource Management subthrust.

As part of the Department of Defense stewardship goal, DoD is charged to maintain and improve the sustainability and native biological diversity of terrestrial and aquatic (including marine), ecosystems while supporting human needs, including the DoD mission [DUSD(ES) Memo "Implementation of Ecosystem Management in the DoD", August 1994]. All of the DoD services have expressed (in formal research requirements and through other mechanisms) the need to better understand ecological processes and trends on military lands, the ecological relationship of military lands to their surrounding lands, and the interactions between mission activities and ecological processes. The goal of the **Ecosystem Monitoring** subthrust is to provide knowledge, tools, and techniques to permit military land managers to evaluate the ecosystems on their installation and to predict the responses to military operations as well as to effectively manage the lands for long term sustainability and use.

This subthrust focuses on addressing science and technology requirements for ecosystem management of DoD military installations. The current R&D focus for this subthrust includes the creation of long term monitoring site(s) on DoD lands to observe ecosystem trends over time, identifying ecosystem change indicators, understanding disturbance within the ecosystem resulting from military mission activities and land management practices, and development of adaptive management practices and tools based on ecosystem monitoring. The challenge for the Ecosystem Monitoring subthrust will be to incorporate the findings/result of ecological monitoring and new understanding of ecosystem processes into the development of practical adaptive management tools for installation resource managers that are transferable across an ecoregion.

Within the Department of Defense, the military services are required to maintain and restore remaining native ecosystems across their natural range of variation, and to ensure long-term sustainability of military training and testing lands and waters in support of the National Defense mission (DOD Instruction 4715.3). The **Ecosystem Restoration and Mitigation** subthrust addresses the research and development needs associated with the restoration of natural systems and their functions and values, with a goal of sustaining the health, productivity, and biological diversity of ecosystems in concert with the mission of military readiness and environmental compliance requirements.

The research and development focus for the Ecosystem Restoration and Mitigation subthrust includes monitoring and managing of invasive species, identification of resilient and resistant plant characteristics, diagnostic tools for restoration, and reclamation technologies. In practice, much of DoD's restoration efforts are engineering driven and site specific without much regard to the significance of the functions in which the site(s) serves within the ecosystem or ecoregion. With the increased emphasis on an integrated ecosystem-based approach to management of Federal, State, and private lands, ecosystem restoration has emerged as an important area of interest. To be fully realized and implemented, ecosystem restoration requires the integration of the understanding of ecological processes into reclamation technologies and engineering practices. The goal of the Ecosystem Restoration and Mitigation subthrust is to identify research and development opportunities that will facilitate this integration.

Ecosystems provide the background for the DoD to maintain its military readiness. To sustain these ecosystems, decisions makers must take into account potentially interactive effects of natural variability and human induced change on ecosystem structure, function and productivity. A key role of science is to provide insights into the potential scale, direction, and nature of that change. SERDP funded research and development in the **Ecological Forecasting** subthrust is aimed at forecasting the ecological response to current and/or expected change using models and other decision-making tools. The current R&D focus for the Ecological Forecasting subthrust includes modeling development, error and uncertainty analyses, alternative future scenarios, and risk assessment tools.

A key driver over the next decade for the Ecological Forecasting subthrust will be urban change in areas surrounding DoD installations. Research and development should have a critical contribution to the establishment of a comprehensive understanding of the dynamics of urban change outside DoD installations and how this change will effect the sustainability of military range lands. Decision tools will be instrumental for the development and implementation of installation-community planning policies, procedures and forums, as well as, serving to facilitate daily management decisions on DoD installations.

Conservation Program

The following lists reflect FY 2000 completed projects and projects continuing into FY 2001. Also included are titles of projects commencing in FY 2001. Complete descriptions of all of the projects for FY 2000 and FY 2001 may be found on the pages referenced in Appendix C - Conservation Project Summaries.

Subthrust: *Ecological Forecasting* — **Page**

FY 2000 Completed Projects

Subthrust: *Threatened and Endangered Species*

Subthrust: *Cultural Resource Management*

FY 2002 Conservation Initiatives

The FY 2002 initiatives reflect an emphasis on (1) U.S. Army's threatened and endangered species user requirements, (2) detection and evaluation of cultural resources as a result of the cultural resource management workshop co-sponsored by SERDP and DoD's Legacy Cultural Resource Management Program in June 2000, (3) the increased pressure on DoD installations to respond to demands from land use changes surrounding installations, and (4) the development of nanotechnologies for the purpose of ecological monitoring.

For FY 2002, there are two new initiatives in the Threatened and Endangered subthrust area. The first is entitled, **Impact of Fog Oil Smoke on Insect Populations Which May Be the Food Source for Threatened and Endangered Species**. The objective of this initiative is to develop and apply a methodology that will allow the quantification of population dynamics, principally decreased, among the insect fauna in areas subjected to "fog oil" smoke generation during military training. Studies will be addressing realistic environmental settings applicable to DoD insectivorous threatened and endangered species. Additionally, the initiative entitled, **Low Frequency (less than 100Hz) Audiogram Technologies for Predicting the Impact of Military Noise on Threatened and Endangered Species**, seeks to develop technologies which will establish the lower frequency end of the range of hearing of a wide variety of threatened and endangered species (excluding the Red-Cockaded Woodpecker) and perform limited proof of principal experiments on representative species. Frequencies of concern are associated with military training, in particular, impulse noise.

The FY 2002 initiative in the Cultural Resource Management subthrust area is entitled **Cultural Resources Management Detection and Evaluation Technologies**. This initiative supports the development of improved technologies to assist in locating and identifying prehistoric and historic archeological sites on Department of Defense (DoD) and Department of Energy (DOE) lands. There is a need to develop and integrate advanced and emerging technologies to more efficiently and cost-effectively manage these types of cultural resources. Potential techniques include both improved models for predicting the location of resources and improved technologies for detecting surface and/or subsurface resources. Non-invasive processes/procedures are strongly encouraged in order to reduce the possible disturbance of human remains and associated artifacts. Ground-truth testing is necessary to demonstrate the feasibility of the proposed technologies and associated procedures.

Under the Ecological Forecasting subthrust, an initiative entitled **Identifying, Characterizing, and Predicting Impacts of Regional Land-use Change on the Sustainability of Military Installations** addresses the current encroachment issues surrounding DoD installations. The overall purpose of this initiative is to increase the understanding of the risks to military operations and training associated with land use change outside of military installation boundaries. More specifically the initiative seeks to identify and examine those land use, compliance, and ecosystem variables, resulting from outside land use change, that represent potential future constraints to the Department of Defense’s (DoD) operational mission(s), and develop the analytical tools or approaches to predict changes in these variables as they represent conflicts to the sustainability of military operations. This initiative should enhance the ability of military installations to understand the implications of external land use change, resource use, and future development policy and how that might impact the sustainability of their lands, ranges, and missions.

A FY 2001 SEED initiative under the Ecosystem Management subthrust, **Development of Miniaturized Sensors to Monitor or Determine Ecosystem Parameters** supports the development of miniature sensors for monitoring one or more of the following environmental parameters: water quality parameters (dissolved O_2, turbidity, etc); waterborne pollutants (metals, PAHs, PCBs, etc), primary production, air quality parameters (NOx, SOx, ozone, particulates, etc), terrestrial parameters (soil moisture, overland flow, vegetative cover), and other indicators of ecosystem health.

Detailed description of the FY 2002 Conservation SONs may be found in Appendix E.

POLLUTION PREVENTION

Introduction

The Pollution Prevention Technology Thrust Area focuses on reducing or eliminating the generation of pollution within the DoD. The application of pollution prevention technologies will influence positively the other DoD environmental Thrust Areas by encouraging the use of innovative technologies and practices such as recycle, recovery and reuse, reducing pollutants to be managed at the source, and promoting the sustainable use of natural resources.

As defined under the Pollution Prevention Act of 1990, pollution prevention means “source reduction” and other practices that reduce or eliminate the creation of pollutants through increased efficiency in the use of raw materials. Source reduction is defined as any practice that reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment, or disposal. SERDP Pollution Prevention does address end-of-pipe recycling of wastes for originally designed uses, such as the recycling of munitions and their materials back into the production of new munitions.

The DoD and DOE have a number of unique functions, such as the development and operation of sophisticated weapons systems which demand specialized, high-performance materials. Many of these materials are toxic and are targeted for voluntary reduction. The challenge to DoD and DOE is sustainability, which translates to finding new, alternative, high-performance materials that are not toxic and/or to determine innovative ways to control the use of toxic chemicals in order to reduce releases and off-site transfers.

Waste minimization programs in the private sector have demonstrated that pollution prevention not only reduces potential harm to the environment, but also saves money. Addressing those pollution prevention technology needs which are not adequately addressed by the private sector will be the focus for DoD and DOE in order to meet their environmental obligations in a cost effective manner. Material substitutions, manufacturing process changes, inventory and stockpile controls, and adjustments to routine daily processes will be required to meet these obligations.

The Pollution Prevention Thrust Area, at the recommendation of the SERDP Scientific Advisory Board, is adopting a proactive approach to provide solutions to the highest priority defense- related environmental problems. The Pollution Prevention Thrust Area, in addition to addressing near term multi-service DoD problems, will also address more forward looking, high-risk, long- term projects to achieve the goals that will be set forth by future regulations. This will be done by designing tools to alert planners to potential environmental issues. SERDP will work closely with military planners, Service research organizations, and the Office of Deputy Under Secretary of Defense for Environmental Security to identify long-term needs for the Department.

The Pollution Prevention Technical Thrust Area Working Group (TTAWG) continues to emphasize a program shift toward the more global, tri-Service issues and on developing seed technologies to address emerging regulatory issues. The TTAWG has envisioned SERDP's role as a facilitator in communication and collaboration to enhance technology transfer and to leverage Service and SERDP resources. This will be achieved through increased interaction with the National Defense Center for Environmental Excellence (NDCEE), the National Center for Manufacturing Sciences (NCMS), and participation in Joint Acquisition Sustainment Pollution Prevention Activities (JASPPA) initiatives.

SERDP continues to use topical studies and workshops as a tool to identify DoD/DOE user needs, to better understand the existing state-of-the-art technology in these areas, and to identify environmentally driven requirements and any industry or DoD initiatives addressing them. In addition to fostering technology transfer, this information is used to help focus the SERDP program on the highest priority issues and to avoid duplication of effort. The DoD environmental community has made significant progress toward reducing the use of ozone depleting chemicals (ODCs), hazardous air pollutants (HAPs), volatile organic compounds (VOCs), toxics release inventory (TRI) listed chemicals, and selected heavy metals in defense industrial operations. Though these efforts were made to develop technologies that could be applied to other systems and processes, most process modifications were optimized for a particular operation at a specific site. Thus, the progress made in discrete technologies and/or application areas has made the task of identifying the remaining environmental requirements within the weapon system structure even more challenging. Specific investments must be based on: (1) environmental concerns shared across the services and affecting multiple weapon system platforms; (2) processes with recurring compliance burden and liability costs; and (3) processes which can be modified to reduce operating costs.

In response to these challenges, SERDP's pollution prevention program has taken a systems approach to address DoD user needs and will continue to work on the next generation of concepts/materials. In FY00, SERDP initiated the "Zero Discharge Depot Analysis." Under the initial phase, Anniston Army Depot (ANAD) was selected as the installation to be analyzed. In September 2000, SAIC submitted their report, which examined 157 maintenance and overhaul processes. It provides a detailed analysis of Environmental, Safety, and Occupational Health (ESOH) concerns, related regulations, and risks associated with each process. In addition, the report examines the weapon systems and programs that drive the usage of hazardous materials and generation of hazardous waste. SERDP and the Services intend to use the recommendations resulting from this initial study to help form the basis for new start projects in the FY 2003 program.

The Air Force, Army, and Navy have each submitted their Pollution Prevention User Requirements, which are prioritized in the DoD Environmental Technology Requirements Strategy (DETRS). These requirements can be grouped into specific environmental concerns. The primary DoD environmental concerns in Pollution Prevention are:

- Identifying alternatives for hazardous and toxic chemicals and materials;
- Reducing the use of hazardous and toxic chemicals and materials;
- Reducing the volume and toxicity of wastes and pollutants through source reduction;
- Improving the efficiencies of mechanical and chemical systems;
- Incorporating environmental ramifications as key evaluation considerations in major system design and acquisition;
- Considering the life-cycle effects of materials and systems; and
- Evaluating the sustainable use of resources.

These DoD Pollution Prevention needs are addressed by the five major sub-thrust areas of Air Emissions, Halon Replacements, Elimination of Chromium and Cadmium, Green Energetic Materials, and Reducing Hazardous Materials, which are further organized as shown in Figure III-8.

POLLUTION PREVENTION	
FY 2000	
25	Total projects
5	Completed projects
6	New Start projects
FY 2001	
27	Total projects
5	Completing projects
6	New Start projects

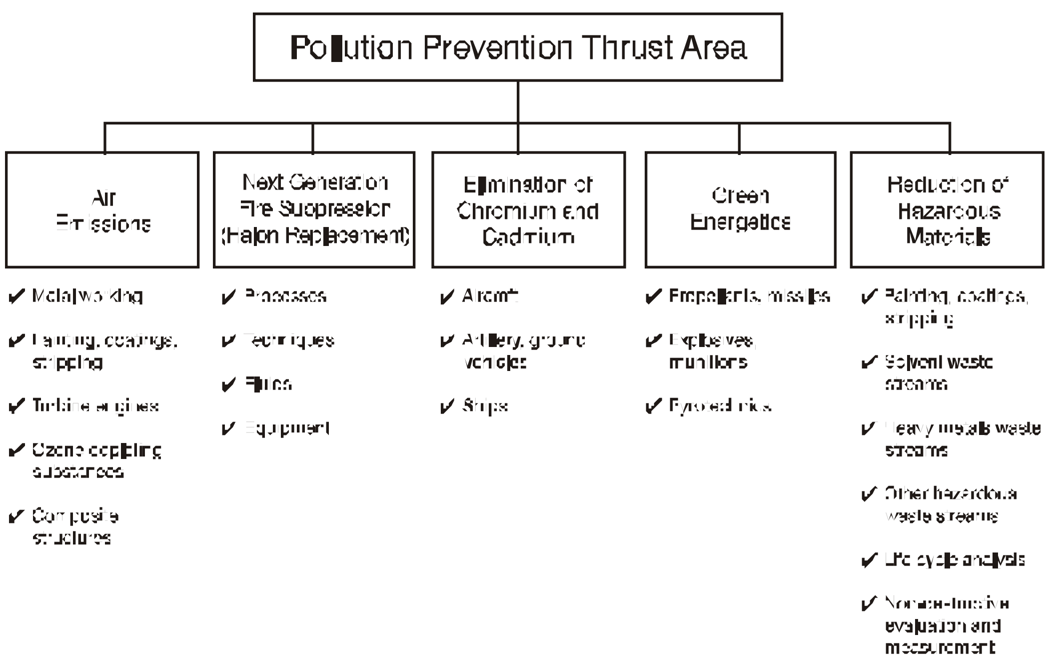


Figure III-8. Pollution Prevention Taxonomy.

The FY 2000 and FY 2001 distribution of SERDP funding for Pollution Prevention among the subthrust areas is shown in Figure III-9. For FY 2000, Pollution Prevention received approximately 27 percent of the SERDP budget. In the out years, Pollution Prevention will continue to grow relative to the three other technology areas of SERDP in order to meet DoD users demands for better, cheaper, and cleaner weapons systems and processes.

Future SERDP Pollution Prevention projects will be selected based on the following general metrics:

- Expected payoff (i.e., potential cost avoidance);
- Magnitude of the environmental problem that the technology will address;
- Clearly identifiable potential environmental benefits and impacts on the defense establishment, regardless of whether the project addresses current, near-, mid-, or long-term needs; and
- Leveraged funding from Services/Agencies applied to the project.

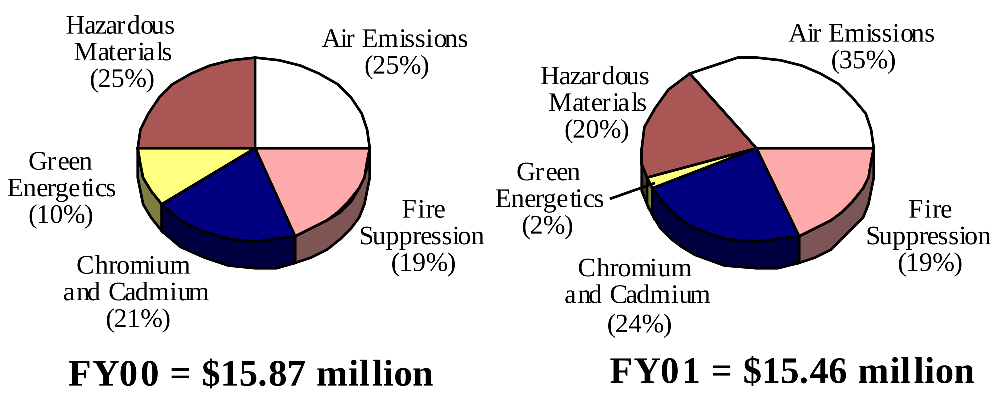


Figure III-9. SERDP Pollution Prevention Funding by Subthrust, FY 2000 and FY 2001.
NOTE: FY00 values represent actual funding. FY01 values are planning figures based upon the President's Budget Request.

Principal Driving Requirements

Congress has enacted several laws that are primary drivers for DoD and DOE to green up their manufacturing, production, and repair operations. Just a few include the Clean Air Act, Clean Water Act, Pollution Prevention Act, Resource Conservation and Recovery Act, Solid Waste Disposal Act, and Toxic Substances Control Act. The White House has also directed the Federal Government through a series of Executive Orders (EO) to take actions to prevent pollution. EO 12856, "Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements," states that the Federal Government should become the leader in the field of Pollution Prevention through the management of its facilities, its acquisition practices, and by supporting the development of innovative pollution prevention programs and technologies. The EO challenged the heads of the DoD and DOE to set goals voluntarily to reduce their agency's total releases of toxic chemicals to the environment and off-site transfers by 50 percent from 1994 baseline figures by December 31, 1999.

During this decade, an increased emphasis has been placed on pollution prevention to reduce environmental impacts associated with DoD weapon systems acquisition. The DoD Pollution Prevention Strategy of August 11, 1994, established a goal to identify and develop environmental life cycle cost estimating tools that inject pollution prevention and other environmental concerns into acquisition decisions. Development and application of modeling and simulation tools to identify and test technical solutions that reduce reliance on toxic materials and processes are required.

Virtually all DoD maintenance and repair activities for weapon system components involve the use of toxic or hazardous substances. The 1990 Clean Air Act Amendments (CAAA), the Resource Conservation and Recovery Act (RCRA), and state and local regulations restrict the emission and disposal of these hazardous materials. Ozone depleting substances (ODS) are being phased out of production under national policy and international (Montreal) protocol. DoD directives require significant reductions in hazardous wastes and development of alternative materials and processes that meet environmental restrictions and allow DoD to continue operations. Operations and training activities at DoD installations and facilities generate large quantities of hazardous, non-hazardous, and special wastes that are expensive to manage and dispose. Within the **Reduction of Hazardous Waste** subthrust, SERDP is funding numerous, wide-ranging projects addressing alternatives to hazardous and toxics chemicals and processes such as for cleaning agents, anti-freeze, corrosion protectors, and coatings. More focused research in this area is addressed in the **Green Energetics** subthrust with projects investigating environmentally friendly ammunition, propellants, and smokes.

In 1999, EO 13123 "Greening the Government Through Efficient Energy Management," and EO 13134 "Bio Based Products and Bioenergy," were signed by the President. In April 2000, EO 13148 "Greening the Government Through Leadership in Environmental Management" directed DoD and other Federal agencies to establish new pollution reduction goals. In response, DoD has implemented three new reduction goals: (1) reducing the Toxic Release Inventory by 40% by 2006; (2) reducing the use of 15 chemicals by 2006 by focusing on replacement of common processes and chemicals; and (3) eliminating the purchase of all Class I OSDs by December 31, 2010. In the **Air Emissions** subthrust, SERDP is funding a wide array of projects addressing reduction or elimination of VOCs in adhesives, lubricants, and sealants, pollutants in composites and low observable coating, and emissions from engines. The research in the **Elimination of Chromium and Cadmium** subthrust focuses primarily on finding environmentally friendly sealants and coatings as well as better application methods. Finally, the replacement of Halon, an ODS, in fire fighting technologies is a major focus of research in the **Next Generation Fire Suppression** subthrust.

Several recent EOs will influence the development of the SERDP Pollution Prevention program in the outyears. In 1998, EO 13101 directed "Greening the Government Through Waste Prevention, Recycling, and Federal Acquisition." It encouraged the expansion of markets for recovered materials, environmentally preferable products, (including biobased products), and established the organizational structure to ensure full accountability. Under this EO, Federal agencies must establish specific goals for (1) waste prevention and recycling or solid waste diversion, (2) affirmative procurement of products that are made with recovered materials, and (3) procurement of environmentally preferable products and services for which a pilot project has been successfully completed. Agencies will annually evaluate their progress toward attaining these goals.

Leveraging with other DoD, DOE, and EPA science and technology programs and industry, the Pollution Prevention subthrust areas focus also on the following research and development objectives:

- Alternative materials and processes to replace defense use of hazardous heavy metals (e.g., lead, nickel) and metallic compounds and hazardous air pollutants;
- Techniques to regenerate, recycle, re-use, and stockpile defense unique toxic chemicals and materials;

- Cost-effective, environmentally preferable packaging and recycling approaches to reduce generation of solid waste from defense-related operations; and

- Predictive models (which include environmental life cycle costing) to aid in the development of environmentally sound weapon systems and platforms during concept development, design, test and evaluation, maintenance (logistics support documentation), and decommissioning.

Pollution Prevention Program

The following list reflects FY 2000 completed projects and projects continuing into FY 2001. Also included are titles of projects commencing in FY 2001. Complete descriptions of all of the projects for FY 2000 and FY 2001 may be found on the pages referenced in Appendix D - Pollution Prevention Project Summaries.

Subthrust: *Air Emissions*

Subthrust: *Next Generation Fire Suppression*

Subthrust: *Elimination of Chromium and Cadmium*

Subthrust: *Green Energetics*

Subthrust: *Reduction of Hazardous Materials*

FY 2001 New Start Projects
None

FY 2002 Pollution Prevention Initiatives

SERDP is proposing six new start initiatives. The six core SONs also include the submission of SEED SONs in these same areas. The primary focus of the FY 2002 program is to investigate the environmental effects of new energetics and materials for future use in the DoD inventory. On the energetics front, hazardous wastes associated with DoD energetic materials life cycles constitute over 40% of DoD's wastes. In the current regulatory environment, the costs of managing these wastes have significantly increased the production, maintenance, and disposal costs of the required energetics materials. The fate and effects of energetic materials on training and testing ranges are also becoming significant issues that will impact the future use of energetics. The 2002 solicitation seeks to investigate the potential environmental effects of a new energetic material CL-20, evaluate the potential of imbedding existing and future munitions to discern their status (e.g., fused or unfused) and reduce future range cleanup costs, and develop environmentally cleaner pyrotechnics technologies. The pollution prevention program will also seek out and develop new technologies for environmentally friendly new materials and repair processes for composites and aircraft weapon systems and identify innovative solutions for solid waste reduction within the DoD and DOE complexes. SERDP will continue to act as a catalyst in fostering the development of next generation concepts and tools, such as improved computational chemistry techniques and models which will help accelarate the development of environmentally friendly DoD materials and processes.

The objective of the first SERDP SON, **Environmental Fate and Transport of a New Energetic Material, CL-20**, is to determine the transport, fate and environmental effects of the new energetic material known as CL-20. The research should focus on the neat compound and its degradation products in one or more of the following areas:

- Transport through the vadose zone and groundwater
- Effects of weathering, and biotic and abiotic degradation and transformation
- Lethal and sub-lethal environmental effects on plants, soil organisms, avian species, terrestrial species, and aquatic species.

The objective of the second SERDP SON, **Remote Location and Identification of Expended Munitions**, is to develop advanced techniques to embed a capability within munitions to allow for the easy and rapid detection and discrimination of fired munitions that failed to detonate or are inert by design. This applies to large projectiles, such as the Mark series bombs (up to 2,000 lbs.), ship-based and land-launched munitions, and to a variety of cluster weapons and their associated submunitions. Specifically, proposed work should address one or more of the following objectives:

- To accurately locate the fired munition in the impact area

- To identify the type of munition (Mark series bomb, howitzer projectile, submunition, spotting charge, etc.)

- To determine the status of individual munitions as to their content (explosive or inert) and, if explosive, the fused condition (fused or unfused)

The proposed technology must not compromise range personnel safety. The proposed technology is expected to reduce the costs of detection, discrimination and removal of UXO. Also required are capabilities to assess buried as well as those munitions lying on the surface, including under/on a variety of terrain (water, desert, forest, mountains, tundra, etc.), and often penetrating a variety of soils, concrete, or armor. Technologies to enhance our ability to detect existing UXO will not be considered under this statement of need.

The objective of the third SERDP SON, **Environmentally Acceptable Pyrotechnic Formulations**, is to develop new formulations for pyrotechnics that are cleaner (i.e., produce non-toxic or smaller waste streams) and more environmentally benign than current formulations. Pyrotechnics can be grouped into six families; decoy flares, illuminating flares, colored flares, smokes (both colored and white), igniters/starters and miscellaneous pyrotechnic items. The focus of this Statement of Need is to reduce the environmental effects of these devices through substitution of materials in the device to reduce or eliminate toxic or carcinogenic constituents or reaction products. Because there are already ongoing projects addressing pyrotechnic igniters/starters, proposals addressing igniters/starters or primers will not be considered. The proposed effort will result in fewer inherent environmental risks than the current devices, provide the same or improved level of performance as the current systems, and provide the same or improved level of safety in manufacture and use.

As part of the proposed effort, the work must include:

- A preliminary assessment of safety risk and a preliminary cost analysis for the proposed process or substitution; and

- A preliminary assessment of potential risk human and ecological health due to exposure from either the newly formulated pyrotechnic device or its reaction products.

The objective of the fourth SERDP SON, **Environmentally Innovative Technologies for Polymer Matrix Composites Reformulation, Fabrication, and Associated Repair Processes**, is to develop environmentally benign resins and novel fabrication/repair processes for polymer matrix composites (PMC) while meeting unique component requirements for DoD systems. Specifically, the goals of this research are to:

- Reduce Nitrous Oxides (NOx), volatile organic compounds (VOCs), hazardous air pollutants (HAPs), and ozone depleting substances (ODSs) as by-products of the manufacturing and associated repair cycle, while not producing other byproducts that are harmful to the environment or humans.

- Reduce hazardous solid waste due to short material shelf life and the resulting debris by-products of the manufacturing/repair cycle.

Areas of research might involve material re-formulations resulting in low/no VOC and HAP resins with increased shelf life of pre-impregnated materials, or eliminating/minimizing the use of autoclave curing, resulting in reduced NOx emissions while minimizing hazardous materials wastes. Alternate adhesives, solvents, and release agents used in fabrication and repair may also be addressed.

The objective of the fifth SERDP SON, **Low Temperature Powder Coatings**, is to develop durable, low temperature (less than 230 degrees F) cured powder coatings or powder coating processes for temperature-sensitive substrates to meet the unique requirements of DoD aircraft/weapon systems. Specifically, the SON's goal is to develop coating materials and processes that eliminate or significantly reduce volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) [greater than 95 % reduction for both VOCs and HAPs] as applied to temperature-sensitive weapon system components. Solvent based coatings will not be considered.

The proposed research must address the issue from a systems level and must yield lower environmental life cycle impact than current processes. Depot and field support issues (maintenance and repair) as well as any component/system specific application issues must be considered in the proposed effort. Additionally, powder coating removal, inspection techniques and touchup techniques should be considered. Baselines for the powder coating (materials, quantities, costs, durability, corrosion protection and environmental impact) shall be established and compared to the existing, conventional baseline coating system of MIL-PRF-23377G epoxy amide primer and MIL-PRF-85285 high solids polyurethane topcoat. The proposed technology must eliminate or significantly reduce VOCs, HAPs, and hazardous solid or liquid waste streams.

The objective of the sixth SERDP SON, **Solid Waste Reduction Associated with Military Rations and Packaging**, is to reduce solid waste associated with military rations through the:

- Development of environmentally friendly packaging and/or the evaluation of improved packaging/storage concepts.
- Reduction in the volume of unused military rations discarded based on expired shelf life.
- Improved separation and salvage/reuse of heating elements or new approaches to provide heat for military rations.

Expected payoffs includes:

- Significantly reduced generation of expired ration stock and packaging waste in the field without adversely impacting warfighter acceptance/consumption of rations.
- Availability of more efficient packaging and the use of more environmentally friendly packaging (e.g., substituting compostable, bio-based packaging materials to reduce landfill volume) will reduce solid wastes in the field.
- Improved packaging/storage concepts to extend food shelf life or reduced packaging requirements will also yield less solid waste.

In addition to these core SONs, SERDP is also soliciting SEED proposals in these six areas to develop high risk/high payoff research and development efforts to address the DoD pollution prevention needs.

The objective of this SEED SON, **Environmentally Benign Antifouling Approaches for DoD Vessels**, is to develop innovative approaches to reduce or eliminate the use of copper for antifouling protection of DoD ship hulls. The development of environmentally benign antifouling methods will result in the reduction or elimination of large quantities of copper, which currently leach into our waterways or end up on drydock floors. Ablative antifouling paints with cuprous oxide toxicant are on about 95% of the Navy's fleet. Copper hull leachate has been identified as a discharge that may cause negative environmental effects. Therefore, in accordance with UNDS requirements, marine coatings will be subjected to copper release rate limits. To date, no effective non-biocidal coatings that meet current performance criteria have been identified.

The objective of another SEED SON, **Environmentally Benign Biological Fouling Control in Heat Transfer Equipment**, is to develop environmentally benign technologies, methods, and processes to prevent biological fouling in heat exchangers, condensers, water piping systems, locks and dams. Biological fouling of these structures and equipment is a chronic and costly problem for the Navy, Coast Guard and the Army Corps of Engineers. The primary approach to control biological fouling has been chlorination. However, the discharge of chlorinated water from land-based cooling systems (including dockside chlorinators connected to a ship) is subject to state implemented water quality criteria. The proposed work shall address technologies, methods or processes that: (1) are effective in minimizing the effects of microbiological and macrobiological fouling, (2) satisfy state and federal discharge requirements, (3) reduce or eliminate requirements for hazardous materials storage, and (4) are economically feasible.

The objective of the final SEED SON for Pollution Prevention, **Environmentally Acceptable Alternatives for Non Destructive Inspection with Fluorescent Penetrant Dyes**, is to develop alternative inspection techniques to replace nondestructive inspection (NDI) techniques which use fluorescent penetrant (FP) dyes or to develop non-hazardous materials for use in the existing FP dye techniques. These techniques shall be environmentally benign and shall meet or exceed the performance of the current FP dye NDI. Volatile organic compounds (VOCs), hazardous air pollutants (HAPs) and hazardous waste streams shall be minimal. Performance shall meet or exceed that of currently used fluorescent penetrant dye NDI techniques and will have reduced toxic release inventory emissions and minimal or no hazardous waste stream. Handling and disposal of the wastes associated with these processes cost the DoD $4 M per year.

Detailed descriptions of the FY 2002 Pollution Prevention Statements of Need may be found in Appendix E.

APPENDIX A
Cleanup Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: Aquifer Restoration by Enhanced Source Removal; CU-368

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Carl Enfield; National Risk Management Research Lab – Ada, OK

FY 2001 FUNDS: $110K

DESCRIPTION: Low-solubility organics such as chlorinated solvents were used and released to the environment in large quantities during the 1950s, '60s, and '70s. These contaminants have migrated through the subsurface and entered groundwater at more than 1,000 Department of Defense (DoD) sites. At these sites, the organic contaminants are found in one of four phases: (1) volatilized within the soil's vadose zone (vapor phase), (2) dissolved in the groundwater (dissolved phase), (3) sorbed to the aquifer solids (sorbed phase), or (4) as a separate non-aqueous phase liquid (NAPL) phase. All of these phases contribute to groundwater contamination.

The limiting factor to satisfactory remediation at over 75 percent of the hazardous waste sites in the United States is the restoration of groundwater quality. The major limitations of the successful use of pump-and-treat technology are related to difficulties in extracting contaminants from source areas where NAPLs exist. The objective of this research is to evaluate extraction processes (solubilization and mobilization), which have been developed at the bench-scale, for their potential to enhance extraction in the source area. The technologies will be evaluated using field pilot-scale cells for side-by-side comparison of technologies.

The proposed work will be a series of field demonstrations of enhanced extraction technologies supported by site characterization and laboratory research required to produce credible field demonstrations and evaluations. The work will focus on remediation of source areas of sites believed to be contaminated by NAPLs at residual concentration (no longer mobile and, therefore, not readily available for extraction by pumping).

The technologies will be demonstrated to determine their performance under a variety of conditions. The tests will be conducted as controlled, small-scale field projects. Each technology will be compared to one or more alternative remediation technologies including conventional pump-and-treat as a reference treatment system. The results of these comparisons will show the differential improvement achieved by one process relative to another. Success of the project will be dependent on the ability to obtain regulatory permission to perform non-standard, pilot-scale evaluations without significant delay.

BENEFIT: It is estimated that over 90 percent of the contaminant mass in the subsurface environment is contained in the source area. Until the source area is remediated or contained, it will not be possible to obtain permanent closure for any of the sites. Pump-and-treat systems are the primary technology in use at sites with contaminated groundwater. Because of their inability to effectively clean contaminant sources, many of them will be operated "in perpetuity." The cost of operating and maintaining these systems is enormous, and the institutional arrangements to keep them operating for tens to hundreds of years do not exist. Bench-scale studies suggest that it will be possible to remove the majority of the NAPL where the source can be identified. The time required for this removal is small compared to the time required if pump-and-treat technologies are used. Estimated costs for groundwater remediation by DoD and other Federal agencies range into the hundreds of billions of dollars, and even incremental improvements in efficiency will justify the cost of the proposed research.

ACCOMPLISHMENTS: Two enhanced dense non-aqueous phase liquid (DNAPL) removal technologies, cosolvent solubilization and air sparging/soil vapor extraction, have been demonstrated at the Dover AFB

National Test Site. Approximately 70% of the DNAPL was extracted during the cosolvent solubilization test. A journal article describing the results of this test was submitted for publication and technical reports are in preparation. Data from the air sparging/SVE test is being evaluated to quantify the effectiveness of this technique. Interim reports for the first two demonstrations have been completed. Demonstration of a third DNAPL removal technology, surfactant-enhanced solubilization, was supported by results from laboratory tests that suggested that the surfactant fluid effectively solubilizes the DNAPL but is not retained by the geologic matrix. The DNAPL release and pre-demonstration partitioning tracer test has been completed in preparation for the third demonstration. This tracer test was run in a vertical flow mode in order to facilitate better contact between the tracer and DNAPL. Preliminary data suggested that there was greater separation of reactive and non-reactive tracer peaks with this approach. Thus, the surfactant flood was then run in this same manner. It was anticipated that removal efficiencies would increase with improved contact between the DNAPL and remedial fluid. The surfactant flood was completed, and the post-demonstration partitioning tracer test was conducted.

TRANSITIO N: The results of these comparisons between alternative remediation technologies will be compiled into a manual. This manual will be prepared for the user community to facilitate design of these systems. The design manual will contain anticipated system performance and will be made widely available to facilitate transition of the technology developed.

PROJECT SUMMARY

PROJECT TITLE & ID: Federal Integrated Biotreatment Research Consortium (FIBRC): Flask to Field Initiative; CU-720

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jeffrey W. Talley; U.S. Army Corps of Engineers Engineer Research and Development Center, Environmental Laboratory – Vicksburg, MS.

FY 2001 FUNDS: $300K

DESCRIPTION: The objective of this project is to develop a set of "realistic" biotreatment processes for the cleanup of several classes of contaminants at Department of Defense (DoD) sites. A single, panacea technology for each contaminant group that can be used at all DoD sites will not be obtained. All treatment processes have technical and economic limitations, and part of the experimental process of this program will be to define these limitations.

The technical approach of this project is to investigate a variety of promising biotreatment processes at the bench- and intermediate-scale. The experiments in this program will be directed toward four major contaminant areas: (1) explosives, (2) chlorinated solvents, (3) polychlorinated biphenyls (PCB), and (4) polycyclic aromatic hydrocarbons (PAH). In some cases, the concepts under investigation have been developed by members of this consortium. In other cases, concepts that indicate promise were taken from current literature and professional affiliation. The processes under development have the potential to be fielded within a reasonable amount of time. This approach will ensure that the DoD will have more cost-effective remediation technology within a time frame required for DoD site remediation activities. Biotreatment processes will be evaluated for the following four major contaminant groups:

- ***Explosives Contaminated Soils And Groundwaters.*** A variety of promising biotreatment techniques will be investigated for remediation of soil and groundwater contaminated with explosives compounds. Explosives contamination represents one of the most prevalent types of organic contamination within the DoD. The research projects in this thrust area are: (a) Discovery of Novel Enzymatic Reactions and Determination of Biodegradation Mechanisms and Pathways and (b) Chemical Transformation followed by Biotreatment for Treatment of TNT Contaminated Groundwater.

- ***PAH Contaminated Soils.*** This class of contaminants represents one of the most regulated due to their carcinogenic properties. Also, because of their large and complex molecular structures, they also represent some of the most difficult of all contaminants to biologically degrade. The research projects in this thrust area are: (a) Management of Bioremediation of Soils Contaminated with Heavy Molecular Weight PAHs (hPAH) through Bioaugmentation and Bioavailability Enhancement and (b) Intermittently Mixed Reactor System for Enhancement of Mass Transfer and Bioavailability in the In-Situ Treatment of hPAH-Contaminated Soils.

- ***Chlorinated Solvent Contaminated Soils and Groundwaters.*** Chlorinated solvents represent a class of contaminants that is detected at more DoD sites than any other contaminant group. The research projects in this thrust area are: (a) Electrically-induced In-Situ Reductive Dechlorination of Chlorinated Solvents and (b) In-Situ Solvent-Extraction-Residual-Biotreatment of Chlorinated Solvents.

- ***PCB Contaminated Soils.*** Soils contaminated with PCBs represent one of the most challenging compound groups under investigation in this project. PCBs are found at many DoD installations due to improper disposal of hydraulic fluids and waste lubricating oils. The research project in this thrust area is: Enhancing PCB Biodegradation.

BENEFIT: The primary benefit of this study is reduced remediation costs associated with development of "realistic" biotreatment processes for the cleanup of contaminated DoD sites. Secondary benefits include: expanded implementation potential of existing and developing biotreatment processes, biotreatment technologies that result in the on-site destruction of contaminants, and increased regulatory and user acceptance.

ACCOMPLISHMENTS: Contaminant-specific progress by the research consortium follows:

- ***Explosives Contaminated Soils and Groundwaters.*** Lab-scale and field-scale studies were conducted to support testing a bioremediation approach for dinitrotoluene (DNT) contamination at Badger Army Ammunition Plant. Microorganisms capable of degrading 2,4 DNT were isolated from the site. A remedial strategy of recirculating contaminating groundwater through the vadose zone in conjunction with the addition of oxygen is currently being tested at Badger Army Ammunition Plant. Although results are preliminary, the system is stable and robust thus far. Products included five peer reviewed publications, three book chapters, and six invited seminars.

- ***PAH Contaminated Soils.*** The pilot scale project and microbial testing were continued. Degradation of hPAHs into 4 ring compounds was demonstrated in the pilot scale study. The time required to achieve 50% degradation of PAHs was decreased by half through bioaugmented landfarming (pans) over the traditional landfarming methods (LTUs). A patent for a method that measures in situ respiration is pending. Several papers have been submitted to peer-reviewed journals, and abstracts have been submitted for poster/platform presentations.

- ***Chlorinated Solvent Contaminated Soils and Groundwaters.*** The Solvent Extraction Residual Biotreatment (SERB) technology was demonstrated. An in situ co-solvent extraction test using ethanol indicated the removal of approximately 70% of the original PCE. Evolution of the microbial population is being followed which will help in later design of both the solvent extraction systems as well as in development of the protocols for enhancements of natural attenuation of chlorinated solvents by reductive dehalogenation. Groundwater continues to be monitored for dechlorination products and microbial activity following use of the SERB technology. An outline for the guidance manual for this technology has been produced. The SERB technology has been transferred through two publications/proceedings and three poster sessions.

- ***PCB Contaminated Soils.*** Preparations for a pilot-scale demonstration are in progress. Three papers have been submitted to peer-reviewed journals this year. One paper has been accepted this year to date. A patent "Mixing Performance of SSR" is in draft.

TRANSITION: This project will develop for the DoD community a biotreatment "toolbox" that can be drawn upon to offer the right process for each site. The technologies produced by this project are intended to serve remediation project managers who want options and well defined limitations of each option made available to them during their remediation process selection. Each process, whether it is traditional or innovative, has technical limitations and risks associated with its fielding. The knowledge of these process limitations will be required to reduce the risks accepted by the installation and regulatory agencies to an acceptable level.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program – McClellan AFB, CA; CU-861

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Jim Lu; McClellan Air Force Base – Sacramento, CA

FY 2001 FUNDS: $340K

DESCRIPTION: The National Environmental Technology Test Site (NETTS) program goal is to enable efficient demonstration of innovative detection, monitoring or remediation technologies, either on an individual basis or in parallel with similar projects, under representative hydrological and climate regimes as found at many contaminated sites in the Department of Defense (DoD). Current environmental cleanup technologies are costly, slow, and largely ineffective. The NETTS program provides test beds for research to fully understand the mechanisms in proposed treatment processes. The NETTS National Test Location at McClellan Air Force Base (AFB) provides test sites to investigate technologies primarily for treatment of unsaturated soils and extracted soil-gas contaminated with chlorinated solvents, as well as ex-situ treatment of contaminated groundwater.

As a NETTS test location, McClellan AFB provides a well-characterized demonstration site for applied research, demonstration, and evaluation of promising remediation and monitoring technologies. McClellan AFB currently has four operational and two planned soil vapor extraction (SVE) systems. All systems have dedicated utilities adjacent to them allowing for convenient slip-stream demonstrations. McClellan AFB's groundwater treatment plant currently services 23 extraction wells. The SVE systems and groundwater treatment facility provide opportunities for demonstrating in-situ and ex-situ techniques for remediating soils and groundwater contaminated with solvents. There are more than 375 groundwater monitoring wells located on and around McClellan AFB.

BENEFIT: Test locations are fully characterized. The NETTS test locations help save time and money for technology demonstrators by providing on-site management, pre-characterization, and timely permitting. An established, dedicated test site enables technology demonstrations to be performed at a cost lower than that of a one-time demonstration elsewhere.

ACCOMPLISHMENTS: In FY00, the McClellan AFB NETTS location accomplished the following: issued six final work plans for FY00 new start projects, issued final reports for seven FY00 project completions, provided support to principle investigators (PIs) for Work Plan development for eleven FY00 new start projects, provided support to PIs for Technology Application Analysis Report preparations for five FY00 field completions, and provided infrastructure and Regulatory Compliance support to twenty on-going and new start projects.

TRANSITION: This project will continue to support the transition of technology as defined by the NETTS Mission Statement that reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and to facilitate transfer of innovative environmental technologies from research to full scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program – Naval Construction Battalion Center, Port Hueneme, CA; CU-863

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Ernest Lory; Naval Facilities Engineering Service Center – Port Hueneme, CA

FY 2001 FUNDS: $820K

DESCRIPTION: The objective of the Navy Construction Battalion Center (CBC) National Environmental Technology Test Sites (NETTS) National Test Location (NTL) at Port Hueneme, CA, is to support demonstration of technologies for characterizing and remediating soil, sediments, and groundwater contaminated with fuel hydrocarbons, waste oil, and fuel additives such as methyl tert butyl ether (MTBE). It provides test sites to investigate both ex-situ technologies for treatment of soils and in-situ technologies for groundwater. The Test Location Manager (TLM) at CBC, Port Hueneme provides programmatic, infrastructure and technical support to researchers for characterization and remediation demonstrations. Programmatic support includes integration of the following: (1) Quality Assurance/Quality Control (QA/QC) procedures, (2) test protocol guidance, (3) demonstration reporting format, and (4) environmental setting, cost-and-performance data retrieval guidance. Infrastructure and its management (operation and maintenance) will include: (1) monitoring wells, (2) in-line sensor network, (3) ex-situ treatment facility with hazardous material handling capability, (4) utilities, and (5) contaminated soil, sediments and groundwater resources. Technical support will include: (1) characterizing and monitoring contaminants, (2) processing permits, (3) supporting stakeholder involvement, and (4) transferring technologies.

BENEFIT: The NTL for fuel hydrocarbon and waste oil provides well characterized test locations, controlled field conditions for comparative evaluations of technologies, uniform evaluation criteria for demonstrations, reporting of results and technology transfer, and cost savings through amortization of infrastructure and management.

ACCOMPLISHMENTS: In FY00, the Port Hueneme NETTS site provided support on the following projects: (1) UC Davis culture (PM-1) injected, (2) methogenic degradation of MTBE surveys conducted, (3) three additional plots installed and cultures injected at the MTBE site, (4) EPA ETV petroleum in soil characterization evaluation hosted (7 vendors), (5) Navy monitoring well comparison cells installed and four sampling rounds conducted, (6) ESTCP bio-barrier installed, and (7) EPA MTBE technology demonstration projects and EPA/CBC/NETTS/state regulators meeting hosted.

TRANSITION: This project will continue to support the transition of technology as defined by the NETTS Mission Statement that reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and to facilitate transfer of innovative environmental technologies from research to full-scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program – former Wurtsmith AFB, MI; CU-864

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Michael Barcelona; University of Michigan, National Center for Integrated Bioremediation Research & Development – Oscoda, MI

FY 2001 FUNDS: $100K

DESCRIPTION: The objective is to operate and maintain a National Environmental Technology Test Sites (NETTS) National Test Location at the National Center for Integrated Bioremediation Research and Development (NCIBRD) which investigates advanced technologies for site characterization, decontamination of hazardous wastes, and remediation of spill and disposal sites. Under NETTS, well-characterized test sites are provided for technologies with evident promise for cost-effective remediation with minimal environmental disruption. These technologies involve on-site and in-situ processes which integrate biological and physicochemical methods for treatment of soils and groundwater contaminated with fuels and chlorinated solvents. NCIBRD is located at the recently decommissioned Wurtsmith Air Force Base (AFB) in Oscoda, Michigan, which has numerous fuel and chlorinated solvent contamination sites resulting from former Air Force activities.

Activities at NCIBRD include an array of research, development, demonstration, testing and evaluation efforts toward the transfer of field and laboratory findings into successful remediation practice. The program focuses on several specific problems relating to the development of core biotechnologies such as the enhanced understanding of microbiology and microbial geochemistry, improved means for implementing biotechnology in engineering applications, and accelerated bioremediation of contaminated soils and groundwater. The majority of the sites at the base have been characterized to some extent. Several of the larger sites are under hydraulic control by way of pump-and-treat systems. A subset of three fuel and chlorinated solvent sites have been characterized geochemically and microbially in support of in-situ bioremediation. The facilities provide a focal point for coordination and cooperation within the broad community of institutions, agencies, and corporations currently attempting to develop these technologies.

BENEFIT: This test location provides significant direct and indirect benefit to the Department of Defense (DoD), Department of Energy (DOE), and Environmental Protection Agency (EPA) Environmental Research and Development (R&D) programs by enabling advanced site characterization and remediation technologies to be evaluated on a common baseline. It also provides standardized testing procedures and cost-and-performance evaluation guidelines which should expedite the approval process for new technologies and in turn facilitate the transfer of those technologies from the development stage to operational use. Field-scale testing at sites which are well characterized and monitored on a continuing basis will save considerable amounts of money in evaluating individual technologies for DoD use.

ACCOMPLISHMENTS: In the past seven years, the Wurtsmith NETTS site has successfully supported the field activities of twenty-three site characterization and remediation technologies. Three sites of major activity have been well maintained. The EGR/NCIBRD Web Site has been established (http://ncibrd.engin.umich.edu) and is supported by a Windows NT, ORACLE driven system. The site is fully operational, providing external access to data from the Wurtsmith site as of June of 2000. The NETTS site currently supports seven ongoing projects.

Due to a reduced need for the types of contamination sites offered by the Wurtsmith NETTS, this site will be phased out by 2002. As the current projects are completed, staff efforts will be reduced and redirected towards decommissioning the NETTS infrastructure at the former Wurtsmith AFB.

TRANSITION: This project will continue to support the transition of the current projects as defined by the NETTS Mission Statement that reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and to facilitate transfer of innovative environmental technologies from research to full scale use. As of June 2000, no new projects were being accepted due to the planned closeout of the site.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program – Dover AFB, DE; CU-866

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Tim McHale; Air Force Research Laboratory – Dover AFB, DE

FY 2001 FUNDS: $500K

DESCRIPTION: This National Environmental Technology Test Sites (NETTS) National Test Location, which is managed by the Air Force Research Laboratory, provides test sites for the application of characterization and remediation technologies for soil and water contaminated by chlorinated solvents. Its centerpiece is the Groundwater Remediation Field Laboratory (GRFL). The GRFL consists of isolated, well-monitored, in-situ controlled release test cells, in which mass-balance studies of the fate, transport and remediation of Dense Non-Aqueous Phase Liquids (DNAPL) may be performed.

Operations consist of long-term monitoring of the site, as well as project support to include injection of the contaminant (Trichloroethylene primarily), demonstration of innovative technologies, and disposal of a minimal amount of waste from the tests. The GRFL program consists of construction of a maximum of five test cells spaced approximately 50 feet apart and constructed and operated in a way to minimize the potential for environmental contamination. Basic design consists of interconnected, steel barrier piling sections (2 feet wide) forming a rectangular pattern (test cells range in aereal size up to 600 square feet). By driving the sheet piling 3-5 feet into the clay aquitard (approximately 30 - 40 feet from the surface), a coffer is formed which prevents vertical and lateral migration outside the confines of the box. There is an additional secondary containment coffer surrounding the primary coffer, which is similarly sealed at the bottom and at each joint. The annulus between the cells is filled with water to produce an inward hydraulic gradient. The annulus and inner cell are continuously monitored for leakage. There are both upgradient and downgradient monitoring wells outside the secondary coffer. Primary risk is that introduced material will escape and contaminate an aquifer. Vertical migration is retarded very well by a twenty foot thick underlying clay layer with a hydraulic conductivity four orders of magnitude less than the overlying strata. Double sheet piling, grouting, monitoring, and developing an emergency pump-and-treat system virtually eliminate the risk from lateral migration. The process for obtaining permits for contained releases is established.

BENEFIT: The GRFL is a unique resource, the primary purpose of which is to provide contained release cells for DNAPL research and development that avoid making the gross assumptions that would be necessary if experiments were conducted in previously contaminated aquifers. DNAPLs are immiscible with and denser than water, and when spilled on the ground, migrate below the water table. Once below the water table, they are difficult to locate and remove. Currently there are no acceptable methods for removing or treating DNAPLs.

ACCOMPLISHMENTS: In FY00, the Dover NETTS site provided support to thirteen ongoing projects, recruited five potential new projects, performed Remediation Technologies Development Forum (RTDF) work, completed USGS support/joint work agreements, abandoned 23 wells, and hosted the DNREC Sampling Meeting and the Dover Visitor's Day. A DNTS web site and interactive CD have been developed. Discovery of MTBE contamination on the Base and the regulatory push to investigate MTBE cleanup methods have expanded the scope of the site.

With the primary objective of promoting collaboration among environmental researchers, a Dover NETTS site Visitor's Day was held August 29, 2000. Approximately eighty researchers, regulators, and policy makers attended including representatives from the Environmental Protection Agency (EPA), Department of Energy (DOE), SERDP, and several State regulatory agency representatives. Through programmatic briefings, technical presentations, and site tours, communication was facilitated among the diverse attendees that will help to further define and improve future research in the environmental field.

TRANSITION: This project will continue to support the transition of technology as defined by the NETTS Mission Statement that reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and to facilitate transfer of innovative environmental technologies from research to full scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Simulators for In-Situ Remediation Evaluation, Design, and Operation; CU-1062

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mark Dortch; U.S. Army Corps of Engineers Engineer Research and Development Center, Environmental Laboratory – Vicksburg, MS

FY 2000 COMPLETED PROJECT

DESCRIPTION: The ultimate goal in remediation modeling is to minimize remediation costs and environmental and human risks while maximizing remediation effectiveness. Toward this end, the general goals of this project were: (1) to develop reliable simulators for promising technologies of interest to Department of Defense (DoD), Department of Energy (DOE), and the regulatory community, and (2) to provide efficient access to multiple remediation simulators through a common user environment amenable to multi-disciplinary cleanup teams. A common, graphical user environment, the DoD Groundwater Modeling System (GMS), was developed for these simulators. The GMS provides conceptualization, parameterization, visualization, and animation capabilities. Additionally, GMS extensions, either ongoing or planned, will provide capabilities for conducting uncertainty, optimization, and cost analyses. The primary technical objectives of this project were to: (1) develop/enhance state-of-the-art remediation simulators for the following technologies: in-situ bioremediation; surfactant-enhanced bioremediation; electrokinetic-enhanced bioremediation; electrokinetic-enhanced mobilization of metals; natural attenuation of explosives; in-situ chemical treatment; surfactant/cosolvent flushing; soil vapor extraction; and air sparging; (2) verify these simulators against available laboratory and field data; and (3) incorporate these simulators into the GMS to provide DoD, DOE, and other users with the computational ability to assess the tradeoff between environmental risk (cleanup level) and cost-effectiveness for a variety of cleanup technologies prior to their implementation.

Remediation simulator development proceeded along three paths, in order of priority: (1) utilize existing, proven remediation simulators where available and consistent with project goals, (2) modify promising groundwater codes to simulate additional technologies as appropriate, or (3) develop new codes as required for efficient simulation of innovative technologies. All simulators were verified against available laboratory and field data. Each simulator were implemented in the GMS. This project strongly leverages technical partnering and collaboration with ongoing and proposed basic and applied research in subsurface flow, contaminant fate/transport, remedial methods, remediation simulation under heterogeneous subsurface conditions, GMS-user environment development, and high performance computing in environmental quality modeling. Technical risk issues involve: (1) uncertainty regarding key processes in complex remediation technologies; (2) the scarcity of experimental or field data for innovative technologies; and (3) the general adequacy of differing computational resources on which to run complex models efficiently. Leveraging against the new Common High-Performance Scalable Software Initiative and Army High-Performance Computing efforts addressed several of the high-performance computing issues associated with simulator development and execution.

BENEFIT: The GMS-based simulators permits the efficient evaluation of multiple remediation technologies for site-specific conditions, allowing selection of effective and cheaper cleanup actions. Such simulators are needed to support advocacy for biogeochemically complex alternatives that are faster, more effective, and/or more cost-efficient than traditional methods. Simulators will improve the remedial design by permitting cleanup specialists to consider multiple scenarios that could increase cleanup effectiveness.

ACCOMPLISHMENTS: Phase-II development of the GMS interface to the UTCHEM model has been completed, including all of the multiphase flow/transport and surfactant flushing features. A tutorial and a new section in the reference manual have been developed. Simulation of the controlled PCE release and recovery by ethanol flushing at the Dover site continued as an evaluation application and tutorial. Field data from the flushing and post-flush partitioning interwell tracer test (PITT) are forthcoming. The latest version of UTCHEM documentation (User's Manual and Technical Documentation) is available for public access on a web site (http://www.pe.utexas.edu/CPGE/UTCHEM/) at the University of Texas. Phase-III of UTCHEM interface development is nearing completion. This final phase of development includes the interfaces to modules for bioreactions and partitioning inter-well tracers. The documentation and user's manual report for the SEAM3D model has been approved for publication. Validation work of the reductive dechlorination package (RDP) at the Pensacola Naval Air Station (PNAS) was continued. RDP implementation into the GMS was continued. The documentation report for the NUFT3D model validation was completed. The model identified the principal reaction mechanisms in the zero-valent iron (ZVI) cell using 36 chemical components and 8 minerals. One important conclusion, based on the chemical reaction kinetics, was that the water velocity through the gate was at the low end of the range estimated in the field. A paper documenting the validation of the OS3D model has been accepted for publication. Revised transport subroutines have been developed to accommodate the MODFLOW outputs from the GMS. Advection and dispersion routines were modified to use (1) flows instead of Darcy fluxes, (2) general 3-D variable thickness grid cells, (3) source/sink terms for wells, rivers, constant head cells, recharge, evapotranspiration, drains, and (4) time-dependent flow fields. Mass balance routines have been added to confirm the accuracy of the formulation. The new routines are being incorporated into the OS3D version for the GMS implementation. The ZVI work with OS3D was included in an invited presentation.

TRANSITION: The project will transition the GMS-based simulators directly to users that include DoD, DOE, EPA, and other groundwater and environmental professionals involved in hazardous waste site cleanup. Use of these remediation simulators will allow more reliable comparison between cleanup level (its duration, environmental risk level) and the cost of each level of cleanup.

PROJECT SUMMARY

PROJECT TITLE & ID: Bioenhanced In-Well Vapor Stripping to Treat Trichloroethylene; CU-1064

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mark N. Goltz; Air Force Institute of Technology – Wright Patterson AFB, OH.

FY 2000 COMPLETED PROJECT

DESCRIPTION: The objective of this project was to demonstrate the potential of combining two innovative, remediation technologies, in-well vapor stripping and in-situ aerobic cometabolic bioremediation, to remediate an area contaminated with separate phase Dense Non-Aqueous Phase Liquid (DNAPL). This hybrid treatment system will be installed and tested at a chlorinated solvent contamination site at Edwards AFB, CA.

Initial operation and testing will consist of turning on the biotreatment well pump and the in-well vapor stripper blower to effect water flow through the system. Flow through the in-well vapor stripper is determined using a tracer. Groundwater levels are monitored using the monitoring wells and the pressure transducers located at the bottom and top of the treatment wells. A bromide tracer (50 mg/L) was added at the chemical addition port of the biotreatment wells. Use of a tracer provided an understanding of the system's hydraulics and allow verification of the modeling results. By comparing bromide concentrations at the vapor stripping well outlet and the surrounding monitoring wells, the non-volatile bromide tracer will provide a baseline, against which trichloroethylene (TCE) measurements can be compared, specifically to quantify TCE volatilization in the vadose zone. The initial operational testing also measured pH, dissolved oxygen and TCE levels in the system. Based on dissolved oxygen levels at the inlet to the biotreatment well, the amount of oxygen added in the well to support the aerobic cometabolism was calculated. Continuous, on-line pH measurements of the vapor stripping well effluent was used to control a chemical feed pump supplying dilute hydrochloric acid to the influent of the vapor stripping well, in order to minimize chemical precipitation. Finally, as part of the initial operation phase, toluene was introduced in a single pulse in the biotreatment wells and then the system will be shut off. This step was used to allow a toluene degrading consortium of bacteria to grow in the bioactive zones, as well as to demonstrate that toluene will be degraded.

During full-scale system operation, toluene was pulsed into the system to provide the time-averaged concentration determined to be necessary based on the preliminary studies. This pulsing schedule was adjusted as necessary to optimize system performance over the six-month course of the demonstration. Oxygen gas will continuously be added at the biotreatment well. Hydrogen peroxide was continuously be added as an oxygen source and bactericide to control microbial clogging at the biotreatment well. The extent of clogging was monitored by measuring pressures at the injection screens of the biotreatment wells.

BENEFIT: The most obvious benefit is that this combination of technologies offers the potential of reducing, in-situ contaminant concentrations at a DNAPL contaminated site over three orders of magnitude. The fact that the technologies are applied in-situ minimizes risk to human and environmental receptors, as well as reduces the costs of pumping water to the surface, treating it, and disposing of it. The technologies can be used at sites with any volatile, separate-phase contaminant that is susceptible to aerobic bioremediation [trichloroethylene (TCE), dichloroethylene (DCE), vinyl chloride (VC), dichloromethane, etc.].

ACCOMPLISHMENTS: Initial groundwater samples were drawn and analyzed for TCE and radon. TCE concentrations as high as 10 mg/L were detected in the lower part of the aquifer. TCE concentrations in the upper part of the aquifer were generally less (by a factor of 2-5) than the concentrations in the lower portion, supporting the original hypothesis that the source (perhaps DNAPL) resides in the weathered bedrock that underlies the aquifer. Radon analyses, conducted as part of a companion ESTCP project, showed an average concentration of 216 pCi/L in the upper aquifer and 642 pCi/L in the lower aquifer. The bioremediation submodel of the BEHIVS model was validated by successfully simulating TCE fate using data obtained from a prior demonstration of in situ aerobic cometabolism. Through the willingness of Edwards AFB, this project will conduct more extensive field studies. The project team is at present considering what additional studies can be accomplished, given the added operational time. Therefore, injection of toluene has been put on hold.

TRANSITION: If successful at Edwards AFB, this project will transition to a full scale application that combines the two remediation technologies, in-well vapor stripping and in-situ aerobic cometabolic bioremediation, to cleanup an area contaminated with separate phase (DNAPL) and dissolved phase TCE.

PROJECT SUMMARY

PROJECT TITLE & ID: Low-Frequency Ultra-Wideband Boom Synthetic Aperture Radar (BoomSAR) for Remote Detection of Unexploded Ordnance (UXO); CU-1070

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Marc Ressler; Army Research Laboratory – Adelphi, MD

FY 2001 FUNDS: $200K

DESCRIPTION: Currently, methods for detecting unexploded ordnance (UXO) involve laborious ground surveys that are slow, dangerous, and impractical for dealing with vast UXO-contaminated lands. Advanced technologies are required which are quicker, safer, and more cost-effective than current approaches. Synthetic Aperture Radar (SAR) is an advanced technology that offers significant potential for quickly and safely detecting UXO. The Army Research Laboratory (ARL) will use their precision measurement asset, called the BoomSAR, in the execution of this project. The BoomSAR is a fully polarimetric radar that operates across a 1-GHz-wide band, from 25 MHZ to 1 GHz. This bandwidth contains low frequencies needed for ground penetration, while maintaining higher-frequency coverage for high-resolution imagery. The ultra-wide bandwidth provides measured range resolution of 0.15 m; the aperture length provides cross-range resolution of 0.15 m. The radar is mounted on a boom-lift that can operate at heights of 5 to 45 m while moving at 1 km per hour, allowing the radar to operate in a strip-map SAR mode.

The goals of this project are: (1) to determine the applicability of low-frequency ultra-wideband (UWB) SAR for detecting and discriminating surface and subsurface UXO; (2) to refine and validate electromagnetic models that can be used to extrapolate UWB SAR performance to other environmental conditions (soils); and (3) to develop detection algorithms for separating UXO from clutter.

BENEFIT: The knowledge gained by this effort will significantly enhance the understanding of the phenomenology of UXO characterization using low-frequency UWB SAR. This effort will also help to determine the utility of the ARL BoomSAR for surveying large regions and detecting and discriminating various surface and subsurface UXO. It is expected that this technology will achieve rapid survey speeds/coverage rates while allowing safe standoff distances during operation; it will also significantly improve the detection, monitoring, and risk management activities at cleanup sites.

ARL's BoomSAR will be used to collect high-quality precision data to support phenomenological investigations of electromagnetic wave propagation through dielectric media. These investigations, in turn, will support the development of algorithms for target detection. Data will be collected at two UXO test sites that have been seeded with a comprehensive variety of inert UXO.

ACCOMPLISHMENTS: Emphasis continued on the modeling and phenomenology components of the research project. Models, measurements, and analysis are converging to provide valuable insight on the efficacy of ultra-wideband synthetic aperture radar for remote sensing of likely UXO-contaminated areas. Correlation between the model predictions and field-measured target signatures is significantly high for the model results to have credibility. Models are being used to assess amplitude, frequency, and angle dependent scattering behavior. The models demonstrate that usable signal levels exist for many types of surface and near-surface UXO; however, the "richness" of the signatures is of concern. Clutter (and the related issue of soil loss) is the critical factor, and the models lag in this domain. Anecdotal measurements indicate that there are considerable differences in clutter competition and loss dependent upon the specific geophysics of the site. Analysis of Eglin and Yuma data continued, and a measure of clutter response has been developed. A specific method for providing an overarching assessment of UWB SAR utility has been outlined. Downstream utility assessments will require detailed site knowledge. Testing of new antennas is underway;

these antennas provide inherently broader angle response, better high-frequency response, and much better polarimetric response.

TRANSITION: The technology developed under this project will transition to users at active test and training ranges, Base Realignment and Closure (BRAC) and formerly used defense (FUD) sites, and numerous foreign countries requiring advanced technologies for locating UXO.

PROJECT SUMMARY

PROJECT TITLE & ID: Using Mode of Action to Assess Health Risks from Mixtures of Chemical/Physical Agents; CU-1073

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Richard Bull; Pacific Northwest National Laboratory – Richland, WA

FY 2000 COMPLETED PROJECT

DESCRIPTION: Mixtures of carcinogenic chemicals in groundwater plumes and soils are a major problem for Department of Defense (DoD) and Department of Energy (DOE) facilities. While there is frequently data available for interactions between chemicals to judge risks from short term exposures, data that describes how interactions influence the development of cancer are very rare. This is largely because of the high costs associated with conducting complex interaction studies over the lifetime of experimental animals. Therefore, it is important that the limited resources that are available for studying interactions be directed towards the development of general principles that can be applied to a wide variety of circumstances.

The hypothesis this project intended to test was whether classifying the modes of action represented in a mixture and knowledge about the dose-response characteristics involved in eliciting a particular mode of action will provide a simpler and more accurate means of predicting the hazards that the mixture poses over a range of exposure situations. Whereas the number of chemicals present in the mixture may be large, the number of modes of action responsible for these effects are small. Each mode of action may have dozens of mechanisms that might contribute to changes in cell birth/death processes, but establishing mechanisms for every chemical is very expensive. The modes of action represented by the three chemicals proposed for study are general to chemical carcinogenesis. Thus, the approach that would result from proving the project hypothesis should be broadly applicable to any mixtures of chemical and/or physical causes of cancer. The top seven chlorinated hydrocarbon solvents found on DOE facilities produce liver cancer by non-genotoxic mechanisms. Two others are clearly genotoxic. Therefore, all modes of action are represented among these compounds. The occurrence of the genotoxic compounds is much less frequent and generally at much lower concentrations than the first seven compounds. Their cleanup levels are less controversial because it is difficult to refute low dose linearity in response for such chemicals and their concentrations rarely exceed drinking water standards of the Environmental Protection Agency (EPA).

BENEFIT: Because of the high cost associated with conducting research to examine biological interactions, the study of every potential interaction of environmental concern is not feasible. This research was directed towards the development of general principles that can be applied to a wide variety of circumstances. The benefits to DOE and DoD from the work proposed are: (1) data bases that can be directly used to assess the risks from mixed exposures to DCA or TCA whether they arise as metabolites from a single solvent [e.g., trichloroethylene (TCE)] or from a mixture of solvents, (2) the data necessary to see how these metabolites interact with a cytotoxic solvent (carbon tetrachloride), and (3) a test of the hypothesis that hazards associated with mixtures of carcinogenic chemicals can be addressed by simply identifying the mode of action and knowing the dose-response relationships for the individual chemicals.

ACCOMPLISHMENTS: The initiation/promotion experiments with DCA, TCA, and carbon tetrachloride (CT) mixtures acting as promoters of carbamate-initiated liver cancer were completed. Preliminary data suggest that the induction of liver cancer from mixtures may have predictable outcomes. The assumption of additivity of low dose responses to tumor promoters generally does not seem to hold. Interactions between low doses of tumor promoting agents had not yet been addressed, hence a final animal experiment was initiated to address the interaction of DCA, TCA, and CT at low doses. The in-life portion of this experiment has been completed. Data is now being summarized, and histological and immunological evaluations are being performed on tumor tissue. Diagnosis and classification of tumors collected from previous experiments are in progress.

TRANSITION: The project has a transition plan that includes: (1) insuring utilization of the data through extensive interaction with EPA; (2) establishing the hypothesis that interactions between environmental carcinogens can be understood on the basis of their individual modes of action; and (3) expanding the concept to other important environmental mixtures.

PROJECT SUMMARY

PROJECT TITLE & ID: Genosensor-Based Ecotoxicity Response Assessment; CU-1081

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kenneth Beattie; Oak Ridge National Laboratory – Oak Ridge, TN

FY 2000 COMPLETED PROJECT

DESCRIPTION: The objective of this project was to develop cost effective methods and instrumentation for directly monitoring genotoxic exposure in a variety of natural ecosystems. Direct measurements of the in-situ biological responses associated with genotoxic exposure of sentinel species in the environment circumvents the difficult problem of bioavailability, since measurable molecular endpoints in resident species are a direct reflection of ecologically relevant exposure. The project intended to implement emerging biochip technology for in-situ monitoring of molecular endpoints of genotoxic exposure, including DNA damage-inducible gene expression pathways, in soil and water ecosystems.

This project intended to employ novel channel glass biosensor chips containing arrays of DNA probes to characterize and monitor the response of soil microorganisms to exposure to genotoxic agents. The biochip device consists of a glass or silicon dioxide wafer containing miniature patches of densely packed pores of 1-10 μm diam., extending through and perpendicular to the wafer surface. DNA probes can be immobilized within individual porous patches at addressable sites across the wafer, to provide a microscopic array of unique nucleic acid hybridization sites. An array of surface-tethered oligonucleotide probes is called a genosensor. The technical objectives of the project was achieved via the following specific tasks: (1) fabricate channel glass genosensor arrays containing DNA probes specific to currently known bacterial stress response and DNA damage-inducible genes; (2) use the "stress response genosensor" to characterize the induction of known stress genes in model soil bacteria exposed in the laboratory to various genotoxic chemicals; (3) utilize a new genosensor- based oligonucleotide fingerprinting strategy to discover new stress response/DNA damage inducible genes; and (4) initiate ecotoxicity surveillance studies with soil and water samples from DOE and DoD sites. The main technical challenges associated with the project included the requirement to extract intact (undegraded) RNA from environmental samples and the low abundance of soil microorganisms deep below the surface. Feasibility studies directly addressed these critical issues in order to define the operational limitations and utility of the approach.

BENEFIT: Expanded capabilities for ecotoxicity surveillance that incorporate a comprehensive collection of molecular endpoints associated with military-relevant compounds would greatly facilitate site characterization, risk assessment and monitoring of the progress of remediation efforts at Department of Defense (DoD) and Department of Energy (DOE) installations. Such capabilities for rapid, multispecies biological endpoint monitoring that is ecologically relevant to cleanup of contaminated sites, should provide a rational basis for reduced cleanup costs, addressing the "how clean is clean?" question. The new technology is expected to enable site closures in a shorter period of time, bringing significant long term cost savings.

ACCOMPLISHMENTS: Initial experiments and computer analysis of the 3'-variable region revealed that DNA probes in this region were not effective in distinguishing between the Pseudomonas strains, while the sequences were sufficiently different in the 5'-variable region. The 3'-variable region is however useful for distinguishing between more diverse species and will be included in the ultimate analysis of microbial populations. In two separate experiments, PCR amplification of genomic DNA extracted from P. aeruginosa was carried out and strain-specific hybridization patterns were obtained. In the popile pan study, plots of contaminated soil were subjected to treatment then sampled and analyzed for contaminants, biomass, PLFA, and abundance of specific gene sequences. Multiplex PCR analyses were performed to assess the abundance of gene sequences encoding a variety of degradative functions as well as 16S rRNA genes as a measure of biomass. Results suggest that gene probes will be useful for monitoring bioremediation in soil. To enable genosensor-based ecotoxicity response testing of field samples, a genosensor system has been established - including flowthough chips, hybridization fluidics, microarray reader, system software, research protocols, and personnel training. Results of the "targeted gene" approach studies suggest that the tandem hybridization strategy can be used to simultaneously analyze expression of numerous genes using Genosensor technology. In the "global gene expression" experiments, over a hundred E. coli genes that are differentially expressed in response to uranium exposure have been revealed. Once several hundred ecologically relevant "indicator" genes have been identified, the oligonucleotide probes for each gene must be selected. To accommodate the complexity of this selection, a comprehensive computer software package for oligonucleotide probe design has been developed. A web site for this project has been organized.

TRANSITION: The long term aim of the project is to install and operate genosensor systems at Oak Ridge National Laboratory (ORNL) and ERDC for use in assessing ecological effects of genotoxic exposure at DOE and DoD sites.

PROJECT SUMMARY

PROJECT TITLE & ID: Negative Ion Sensors for Real-Time Downhole DNAPLs Detection; CU-1089

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Gregory Gillispie; Dakota Technologies, Inc. – Fargo, ND

FY 2001 FUNDS: $133K

DESCRIPTION: Location of DNAPL sources and reliable estimates of their masses are crucial for cost-effective cleanup. No currently available method can accurately and efficiently define the subsurface distribution of chlorinated solvent DNAPLs. The objective of this project is to develop a Site Characterization and Analysis Penetrometer System (SCAPS) probe which can detect, locate, and quantify the subsurface distribution of Dense Non-Aqueous Phase Liquids (DNAPLs) in the soil. The key probe elements are a heated membrane interface and a sensitive, fast-responding downhole detector. Performance objectives have been established as follows: sensor responsiveness to all common organochlorine compounds, vapor limit of detection of 1 ppmv, selectivity better than 5000:1 relative to fuel hydrocarbons, less than 3 second response time, and automatic operation as the probe is advanced by a cone penetrometer or Geoprobe.

The research objectives are to characterize the existing Polytetrafluoroethylene (PTFE) membrane's time-and temperature-dependent permeability for chlorinated solvents, fuel hydrocarbons, water, and oxygen; identify, select, and evaluate promising alternative membrane materials; find the material transfer efficiency as a function of distance from the membrane, soil type, temperature, and moisture; and optimize sensor performance, reliability, and ease of operation. Three sensor approaches which exploit the high electronegativity of chlorinated compounds have been identified. They are thermionic ionization sources, a photoemissive electron capture detector (PE-ECD), and a photoemissive ion mobility spectrometer (PE-IMS). The former two will be investigated in this effort. Risk is relatively low because the heated membrane is already in commercial use and preliminary laboratory data have been acquired for the sensors.

BENEFIT: Using today's technology, the cost to remediate Department of Defense (DoD) sites alone is estimated at $35B. Annual costs greater than $500K for containment and monitoring a single DNAPL plume are typical. If successful, the sensors developed in this project will provide more cost-effect remediation owing to improved spatial resolution for delineation of DNAPLs source terms, lower sensor acquisition and operating costs, and sensor compatibility with other chemical and physical sensors. Subsidiary benefits include an improved membrane interface for all types of volatile organic compound (VOC) analysis (uphole or downhole).

ACCOMPLISHMENTS: In FY00, field testing of the Halogen Specific Detector (XSD) and Photoionization Detector (PID) sensor proceeded. A thermocouple temperature sensor was embedded into the XSD heater reactor core to monitor changes in core temperature as the sensor assembly is driven into the earth to correct for baseline fluctuations. Preliminary field data have been collected at a local chlorinated site to assess the efficacy of this modification. Efforts have begun to model these changes to account for the drift. The PID has performed comparably well to a commercially available GC detector under specific conditions. Generally good agreement of the data was observed between the XSD and PID. In an effort to better understand XSD operation and to make minor engineering changes, the ability to make in-house replacements for key data has been developed for the sensors. The use of a universal umbilical cable that can be employed with either the XSD or the PID sensor was demonstrated. The universal umbilical cable provides savings in resources and time for field deployment of both sensors. In FY00, the replaceable membranes developed by Geoprobe System were incorporated in the coating on the MIP membrane to provide better coverage and less water transfer. The new membranes will be compared with conventional membranes and evaluated for their ability to preclude the transport of water across them while maintaining a high flux of VOCs. A push emulator that allows replication of the action in which the MIP and sensor combination moves through ground became operational in early June. The electronic control module (ECM) was completed and installed. Experimental strategies are currently being developed in conjunction with the push emulator to provide useful data about push rate, push protocol, effects of soil type, and contaminant concentration.

TRANSITION: The project intends to transition through to the Environmental Security Technology Certification Program (ESTCP) for a full scale demonstration/validation in cooperation with Air Force Center for Environmental Excellence (AFCEE) and Environmental Protection Agency (EPA)-Ada, OK. The researchers also have identified the potential for licencing the sensor technology through a third party.

PROJECT SUMMARY

PROJECT TITLE & ID: Integrated Geophysical Detection of DNAPL Source Zones; CU-1090

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Grimm; Blackhawk Geometrics, Inc. – Golden, CO

FY 2000 COMPLETED PROJECT

DESCRIPTION: The objective of this project was to provide cost-effective three-dimensional (3-D) geophysical imaging of the geological control on Dense Non-Aqueous Phase Liquid (DNAPL) distribution and migration at different spatial resolutions and, at the highest available resolution, to directly image DNAPL. Specifically, the project intended to develop a three-fold approach to characterization of physical heterogeneity controlling DNAPL migration and the ultimate imaging of DNAPL distribution in the subsurface: (1) joint 3-D tomographic inversion of surface seismic refraction and electrical resistivity data to broadly delineate subsurface geology; (2) high-resolution joint 2-D/3-D crosshole tomography using downhole seismic and electrical sources and sensors in permanent 4-inch wells and/or temporary 2-inch boring; and (3) utilization of the same downhole electrical sensors to perform IP tomography to image DNAPL with the geological constraints from the above two steps. This three-fold approach may provide new cost-effective, minimally invasive technologies for 3-D geophysical imaging of DNAPL without producing any secondary waste.

BENEFIT: The results of this research included computer software, downhole seismic, and electrical instruments, and case histories focused on Department of Defense (DoD)/Department of Energy (DOE) sites. The direct benefit of this integrated package is the unique capability to produce high-resolution 3-D images of geological structures and DNAPLs in the subsurface. Collecting field data and conducting 3-D computer tomographic imaging for monitoring DNAPL migration can be completed in real time. When this approach becomes available, it will facilitate the design of new treatment/remediation technologies. Based on the image of DNAPL distribution and its geological controls, it can also help improve risk assessment and estimate the realistic cost for remediation alternatives. Collecting 3-D surface seismic and electrical data may take 2 days. Downhole seismic and direct current (DC) resistivity measurements may take 1 day. Downhole IP measurements need only a few hours.

ACCOMPLISHMENTS: In FY00, seismic and electrical tomography construction of the cone-penetrometer seismic-source housing, actuator, and cables by Sandia National Labs and Applied Research Associates (ARA) was begun. Work on the basic Java-language interface for the joint seismic and electrical tomography was begun. The interface is fully general and expandable for different kinds of geophysical methods in the future. The graphical-user interface allows selection of geophysical methods and control of the joint inversion. There are as yet no data- or model-display graphics.

TRANSITION: Providing a successful initial proof-of-concept study, the project has a transition plan that includes the possible integration with existing systems such as SCAPS to apply the technology developed. Other potential users of the three-dimensional geophysical imaging of DNAPL distribution and migration include: the Air Force Research Lab, Sandia National Lab, and Lawrence Berkeley National Lab.

PROJECT SUMMARY

PROJECT TITLE & ID: Innovative Seismic System for Buried Unexploded Ordnance Detection and Classification; CU-1091

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Peter Krumhansl; BBN Systems and Technologies – Cambridge, MA

FY 2001 FUNDS: $100K

DESCRIPTION: The objective of this effort is to investigate and develop a new Seismic Ordnance Detection System (SODS), which can improve the discrimination of unexploded ordnance (UXO) from clutter and thus reduce the number of excavations required during cleanup. The new seismic sensor will sense the mechanical properties of buried objects rather than their magnetic or electrical properties. The SODS system will operate in a manner similar to an active sonar system, with a mobile seismic array which sends broadband vibrational energy into the ground. These waves when they encounter an object with anomalous mechanical properties cause the object to rotate, translate, and to "ring," scattering energy back to the surface. These echoes will be received by an array of geophones and digitally recorded. The received signals are beamformed to locate the objects and to analyze the characteristic echo from the object. These characteristic echoes when used in conjunction with the magnetic and electrical response will more efficiently differentiate UXO from inert objects. After development and characterization of the performance of SODS, it can be used as one of a suite of sensors that can be tailored to specific site conditions and UXO types. This will significantly reduce survey and cleanup costs, especially in areas with high metal clutter or environmental degradation of the performance of other sensors.

The technical approach for the investigation and development of the SODS consists of: (1) performance of an initial feasibility study to analyze the practicality of seismic UXO detection using short wavelength shear waves; (2) development of a proof-of-concept SODS for testing; and (3) evaluation of the proof-of-concept SODS in controlled testing. The system simulation of SODS will be based on computer modeling and field measurements of seismic wave propagation and noise. The second phase will utilize seismic sources and receivers that provide greater bandwidth, increased source level, and better earth coupling than are commercially available while engineering a practical mobile array of seismic transducers that can be used to efficiently collect seismic data. The third phase will include refining of the proof-of-concept system through diagnostic tests and analyzing detections of UXO culminating in an initial evaluation of SODS in multi-sensor tests and an analysis of false alarm reduction using the seismic data in a sensor fusion process.

BENEFIT: The project intends to provide to SERDP: (1) a fully developed SODS that will significantly improve the accuracy of UXO site characterization and reduce excavations and cleanup costs; (2) a SODS that will provide UXO detection and classification capabilities in environments where other sensors perform poorly; and (3) a SODS that will detect non-metallic ordnance and other buried wastes or structures.

ACCOMPLISHMENTS: Analysis of the field data from the proof of concept system tested in 1999 was begun. Imaging of this data provided the first UXO seismic target response data from a 155mm shell. The data was analyzed to guide refinement of the proof of concept system, particularly with respect to high frequency signal coherence. Potential improvements were identified for the seismic source and receiver array. A tradeoff study of seismic arrays was then performed to improve reverberation rejection and improve resolution in space. Signal coherence was analyzed and determined to be lost above 1200 Hz. The seismic source amplifier was redesigned to reduce distortion products, and the source coupling was reduced in size to better approximate a point source. The new source components and receiver array were analyzed, and more careful measurements of signal coherence in the field were obtained. New detection data was collected with a 155 mm shell, a 105 mm shell, and fragments with the new array design. The implication of these tests is that shear waves will not be useful for exciting and beamforming high frequency resonance in UXO. Thus, focus has now been shifted towards use of P waves. New arrays that work with the naturally occurring propagation characteristics and utilize short horizontal distances to the target and high channel count for array gain are now being tested. Initial results from the new array geometry indicate strong detected target response from a 155 mm shell, but with significant complexity in the response. Further field work in different soils and analysis of this data will follow.

TRANSITION: The project intends to transition through to the Environmental Security Technology Certification Program (ESTCP) to develop a fieldable Seismic Ordnance Detection System prototype.

PROJECT SUMMARY

PROJECT TITLE & ID: In-Situ Clay Formation: A New Technology for Stable Containment Barriers; CU-1093

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Joanne Fredrich; Sandia National Laboratory – Albuquerque, NM

FY 2001 FUNDS: $100K

DESCRIPTION: A new type of containment barrier with a potentially broader range of environmental stability and longevity could result in significant cost-savings to the Department of Defense (DoD) and Department of Energy (DOE). This project intends to precipitate clays in-situ in porous geologic materials by building on the technologies that exist for colloidal or gel stabilization. Unlike colloidal or gel barriers, however, a precipitated-clay barrier does not require saturated conditions to be functional. Thus, it can be emplaced without loss of performance in the vadose zone as well as areas with fluctuating water tables. Clays have the advantage of being geologically compatible with the near-surface environment and naturally sorptive for a range of contaminants. The precipitation of clays in-situ in soils and sediments should result in (1) reduced permeability and hydraulic conductivity and (2) increased mechanical stability through cementation of soil particles. By analogy with natural diagenesis in sedimentary rocks, the researchers intend to engineer "artificial" lithification in soils and sediments. Unlike natural diagenesis, however, the time-scale for clay growth will be accelerated greatly from more than tens of thousands of years down to a few weeks.

The technical approach is multidisciplinary and involves the following: (1) confirm published results suggesting that clays can be precipitated in a few weeks to months from aqueous gels; (2) design an optimal gel composition that will maximize clay yield and crystallization rate, while maintaining injectability into porous soils and sediments; (3) test the barrier formulation in laboratory experiments; and (4) test the method in a field experiment. The critical key step in developing the new barrier technology will be to successfully optimize the formation of clays from aqueous gels under ambient conditions. Therefore the first year of the project will be focused on this step. However, researchers will also initiate the laboratory experiments and measurements (flow properties and mechanical stability) in order to address technical details that may arise with the materials or experimental design. Gel composition will be designed using approaches taken from the literature involving reactions and additives known to accelerate clay formation. Emphasis will be placed on characterizing the clay with respect to quantity, composition, and crystallinity. Emplacement of gels in laboratory tests will emulate field technologies such as permeation and jet grouting, and soil-mixing.

BENEFIT: The results from this project will yield a new barrier technology that potentially has a broader range of mechanical and chemical stability and therefore, can be applied in a broader range of environments ranging from arid to humid, and to specific contaminants, ranging from Dense Non-Aqueous Phase Liquids (DNAPLs) to metals. DoD and DOE cleanup sites are located in a wide range of environments across the country and have a range of contaminants. The new barrier technology should also possess greater longevity requiring less maintenance over the long term and less risk of remediation due to barrier failure or leakage. Total cleanup costs to the DoD and DOE should be substantially reduced due to the longer lifetime of the barrier. Once developed, it is anticipated that the implementation cost of the new barrier technology should be on the order of the least expensive chemical grouting technologies currently available.

ACCOMPLISHMENTS: In FY00, two to three orders of magnitude reduction in hydraulic conductivity were obtained in column experiments in which mesoporous silicate materials were precipitated in-situ in quartz sediment. Hydraulic conductivity experiments in quartz sediment columns were conducted in the presence of in-situ precipitated mesoporous aluminosilicate materials and hydrotalcites. Stability of Magnesium-Aluminum hydrotalcites was obtained in the simulated ground water solutions. A manuscript has been accepted for publication in *Environmental Science and Technology* on sorption of hydrophobic organics by mesoporous silicates and stability of mesoporous silicates in simulated ground water.

TRANSITION: The project has a transition plan that includes: (1) full-scale demonstration of the clay formation technology at a DoD site; (2) pursuit of cooperation with industry and consortia (i.e., Remediation Technologies Development Forum); and (3) direct sharing of information on the methodology to DoD and DOE installation managers.

PROJECT SUMMARY

PROJECT TITLE & ID: Environmental Impacts to the Chemical Signature Emanating from Buried UXO; CU-1094

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. James Phelan; Sandia National Laboratory – Albuquerque, NM

FY 2000 COMPLETED PROJECT

DESCRIPTION: The objective of this project was to develop a validated subsurface transport model that can be used to predict the spatial and phase specific concentration of chemical signature molecules derived from shallow unexploded ordnance (UXO) under the influence of specific environmental conditions. Other government programs are developing chemical detector platforms that can provide a separate unique signal to classify subsurface objects identified with existing geophysical systems. It is estimated that eleven million acres of land needs assessment to identify subsurface UXO - with costs estimated to be about $1.4M/acre. The ranges where UXO can be found are distributed throughout the country where environmental conditions vary significantly. The hypothesis of this project was that these environmental conditions will have a significant impact on the transport of chemical signature molecules from subsurface UXO to the surface before presentation to a chemical detector system. Through system analysis, team members showed the ranges and/or combination of environmental parameters that improve or constrain the transport of chemical signature molecules to the chemical detector system. This analysis will enable end users to better understand the merits and limitations when looking to deploy this chemical detector technology.

The first task was to perform a sensitivity analysis of known input parameters in a one-dimensional analytical contaminant transport model, expand this model to assess two-dimensions to explore the surface area footprint from buried UXO, and modify an existing numerical simulation code (T2VOC) (precipitation/evaporation, temperature cycling, liquid diffusion) for use as the complete systems analysis tool. Inverse modeling was used to assess input parameter sensitivity and as a tool for the design of laboratory validation experiments in task three. Task two involved the measurement of specific transport parameters currently not available in the literature for explosive signature molecules. These include temperature dependent water solubility, vapor-solid sorption as a function of soil moisture content and source-term emission rates. Task three was a laboratory validation study that confirmed the most critical parameters included in the simulation model. Task four utilized this validated model to assess the impacts of environmental conditions on the transport of chemical signature molecules from shallow UXO and support end-user queries on the utility of chemical sensor platforms for the classification stage in the identification of true unexploded ordnance.

BENEFIT: This project will provide Department of Defense (DoD) with a new tool to assess the functionality of chemical detector platforms in service to classify shallow UXO from non-UXO. Use of the model, simulations, and systems analysis will improve the decisions made on the utility of chemical detector platforms in a variety of environmental conditions that are expected to have an important role in the transport of chemical signature molecules from shallow UXO. If chemical detector platforms can meet the performance requirements for many application sites, a substantial savings can be expected in reducing the number of non-UXO items treated as UXO during range cleanup activities.

ACCOMPLISHMENTS: Evaluation of the source term data from SouthWest Proving Ground in Hope, AR showed soil chemical residue data near detection thresholds with no discernable differences between live and inert ordnance when compared to background areas at the site where no ordnance was found. Post-shot immersion test results for the mortars indicated no detectable leakage from the units. "Old" ordnance and "new" ordnance did not produce a significant chemical signature suitable for chemical sensing. Using source flux data from landmines with weather data has shown the importance of wetting and drying events for expression of the chemical vapors over surface soils using the T2TNT model. A potential value in an operational strategy for chemical sensing for buried landmines exists but not so for ordnance. The majority of data from Kaho'olawe, HI confirmed that chemical sensing to discriminate live ordnance is not likely. A few strong soil residues from very old ordnance were observed; however, in order for chemical sensing to be a viable discrimination technology, a very consistent correlation is necessary.

TRANSITION: The project has a transition plan that includes: (1) sharing performance targets directly with developers of commercial chemical detector systems; (2) making available operational strategy information to end-users; and (3) pursuing advancement of the chemical detector platform through a demonstration/validation field testing program, such as the Environmental Security Technology Certification Program (ESTCP) or the U.S. Army Night Vision Lab.

PROJECT SUMMARY

PROJECT TITLE & ID: Assessment and Prediction of Biostabilization of Polycyclic Aromatic Hydrocarbons (PAH) in Sediments; CU-1095

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Jeffrey W. Talley; U.S. Army Corps of Engineers Engineer Research and Development Center, Environmental Laboratory – Vicksburg, MS

FY 2000 COMPLETED PROJECT

DESCRIPTION: The objectives of this research were to identify those factors affecting biostablization of Polycyclic Aromatic Hydrocarbons (PAH) in sediments and to develop the technical basis for enhancing natural recovery processes for the biotreatment of PAHs in dredged material. The key questions to be addressed in this research was: (1) Where exactly at the microscopic scale do PAHs reside on aged sediments?; (2) How are the microscopic-scale locations of PAHs on sediments dependent on sorbent carbon location and type?; (3) What are the distribution of binding activation energies for desorption of PAHs from sediment particles, and how does this correlate with information on PAH association with sorbent carbon type?; (4) How does the effectiveness of bioslurry treatment of dredged sediments depend on the locations and associations of PAHs with sorbent organic matter and distributions of binding activation energies with respect to removal of specific compounds, the fraction of labile and resistant PAHs, and the toxicity of residual PAHs?; and (5) How may knowledge of the association of PAHs with sorbent carbon type and location, and distribution of binding activation energies, be used to assess and predict the overall performance of bioslurry processes for biostablization of PAHs? This research assessed the fundamental character of the binding of PAHs at the microscopic scale in parallel with bioslurry treatment and ecotoxicological testing, to show how the nature of PAH association with sediments relate to biostablization, achievable treatment endpoints, toxicity, and bioavailability. The work explored mechanisms controlling PAH sequestration using novel spectroscopic techniques to examine at the microscale the distributions and associations, and binding energies of PAHs in sediments.

BENEFIT: The potential benefits of this research include: reduced treatment costs, improved evaluation and design for clean-up technologies, greater regulatory and public acceptance of biostablization, increase in the reuse/recovery opportunities for treated contaminated dredged materials, and potential application for in-capped sediments.

ACCOMPLISHMENTS: Results from thermal program desorption (TPD) tests, carried out at WES, of PAHs from several standard mineral and organic materials were analyzed by comparing results of TPD analysis of pure PAHs with changes in vapor pressure and temperature of the pure PAH compounds. A paper was finalized describing and analyzing the results of TPD analysis of the standard materials. A finite difference mathematical model was developed to describe the mass transfer of PAHs from sediment coal-derived particles during room temperature desorption and thermal program desorption tests. A paper is being finalized describing the new understanding of the mechanism governing the sorption and release of PAHs from coal-derived particles, and an award-winning poster was presented. At Stanford University, tests were carried out to investigate the presence of PAHs on coke. The paper on PAH formation on coal during heating submitted to the Israel Journal of Chemistry was accepted for publication. At WES, TPD analysis was carried out on separated fractions of biotreated sediment. Ongoing work at NRL has been aimed at developing and optimizing in situ PCR techniques in order that contaminated soil samples can be examined routinely for microscale bioavailability of PAHs.

TRANSITION: The project has a transition plan that includes dissemination of results through established scientific communications channels, as well as proposed partnering efforts with the Army Research Office and the Gas Research Institute.

PROJECT SUMMARY

PROJECT TITLE & ID: Processing Techniques for Discrimination between Buried Unexploded Ordnance and Clutter Using Multisensor Array Data; CU-1121

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Thomas Bell; AETC, Inc. – Arlington, VA

FY 2001 FUNDS: $408K

DESCRIPTION: The objective of this project is to develop a reliable technique for discriminating between buried UXO and clutter using multisensor electromagnetic induction sensor array data. The effort builds on existing research which exploits differences in shape between ordnance and clutter to include the effects of other distinctive properties of ordnance items (fuze bodies, driving bands, fin assemblies, etc.).

Specifically, the project intends to perform tests in the less than 100 KHz domain. The effort will develop: (1) models for the ordnance signature and its constituent parts; (2) procedures for determining target characteristics from multisensor data using the signature models; and (3) decision rules for discriminating between buried UXO and clutter.

BENEFIT: The project aims to provide effective tools for discriminating between buried unexploded ordnance (UXO) and clutter in the context of environmental cleanup. In spite of the recent advances in UXO detection performance, false alarms due to clutter (signals incorrectly diagnosed as having been caused by UXO) remain a serious problem. With traditional survey methods, the Army Corps of Engineers finds that 85-95% of all detected targets are not UXO. Since the cost of identifying and disposing of UXO in the United States using current technologies is estimated to range up to $500 billion, increases in performance efficiency due to reduced false alarm rates can result in substantial cost savings. The product of this research is primarily processing algorithms and procedures for using existing sensor technology within the less than 100 KHz domain.

ACCOMPLISHMENTS: In FY00, the project analyzed electromagnetic induction (EMI) response from clutter objects, refined the baseline model, developed basis functions to describe UXO with driving bands, and began work on parameter estimation procedures. Inversion techniques to extract model parameters from EMI data were evaluated. Three methods have thus far been investigated including: (1) exhaustive search, (2) steepest descent (via downhill simplex), and (3) simulated annealing. Exhaustive search is the most simple, robust, and time consuming. Steepest descent is faster yet more prone to becoming trapped in local minima in parameter space and is therefore less robust. Simulated annealing is robust against becoming trapped in local minima but requires more time. Problems have been discovered for which simulated annealing performs better than steepest descent, and vice-versa. These methods continue to be investigated. Progress in characterizing non-dipole effects, which are a source of modeling error, was made through use of physics-based empirical correction terms. To date, experience on this project has indicated that EMI response contains significant target-specific information which is affected by small changes in sensor position and orientation relative to the target - implying that very accurate positioning (sub millimeter) would provide an advantage for target discrimination. Also, two manuscripts covering aspects of this project were accepted for publication in IEEE Transactions on Geoscience and Remote Sensing.

TRANSITION: Primary products are ability to optimize EMI sensor array configuration and effective processing algorithms for EMI data. These may be directly transitioned to modify the MTADS platform and data analysis system. These plans include introducing measurement techniques and processing algorithms in commercial survey work. The research effort also entails direct involvement with the user community.

PROJECT SUMMARY

PROJECT TITLE & ID: UXO Discrimination by Mid-Frequency Electromagnetic Induction; CU-1122

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kevin O'Neill; U.S. Army Corps of Engineers Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory – Hanover, NH

FY 2001 FUNDS: $295K

DESCRIPTION: This project will perform basic research on sensor development, sensor utility, and signature possibilities in the uncharted 25 kHz – 300 kHz Medium Frequency - Electromagnetic Induction (MF-EMI) electromagnetic frequency band, for induction sensing of buried Unexploded Ordnance (UXO). The goal is to provide enhanced discrimination of ordnance from non-ordnance, and thereby reduce false alarm rates during field surveying. This will be accomplished by innovative instrumentation development in the MF-EMI band, in tandem with new modeling work.

Technical objectives for this project include: (1) Perform lab measurements of soil electrical properties, including seasonal effects, for samples relevant to UXO sites in order to quantify expected subsurface signal loss rates; (2) Extend and verify suite of computer programs to achieve rigorous 3-D solution of the physics of response by non-idealized UXO and non-UXO targets in realistic environments in this frequency range; (3) Produce high fidelity simulations in time, space, and frequency domains of the response by a wide range of specific UXO morphologies and dispositions, and by common non-UXO targets (fragment clusters, tin cans, open shapes, etc.) in realistic environments; (4) Obtain measured induction responses for array of UXO and non-UXO targets, using technology to be developed and exploiting existing data bases where possible; and (5) Use all of the above to identify distinctive UXO signature behaviors, and their discernibility relative to the environment, for combination with those being obtained in frequency ranges both above and below 25 KHz - 300 KHz.

BENEFIT: This work builds directly on recent progress in innovative EMI signature identification in the lower frequency EMI range (100 Hz – 25 kHz) and thereby amplifies its impact. As basic research it will not provide immediate answers, but is directed towards aiding in: (1) Substantial reduction of the false alarm rate in UXO field surveying; (2) Cheaper remediation of UXO hazard sites; (3) Faster and safer surveying of potential hazard sites; and (4) Computational and modeling tool development for wide range of related electromagnetic applications.

ACCOMPLISHMENTS: A numerical modeling system that succeeds in simulating scattering from metallic objects when electromagnetic penetration is slight but cannot be ignored has been developed. All fundamental numerical codes have been completed and tested. These codes include a general axisymmetric code and a 3-D code. Both were designed to operate reasonably well over all frequencies for material homogeneous objects as well as bodies with sections made of different metals. In addition, another specialized "thin skin depth" code has been completed and tested. It is designed to handle optimally the problematical domain in which magnetic field penetration of the target is slight but cannot be ignored (a common occurrence over much of the EMI spectrum but particularly in the higher frequencies). These codes are now being integrated into a single package. The numerical work has been written up rigorously, presented at an international forum, submitted to two others, and submitted to an IEEE journal.

A measurement system has been designed and substantially debugged at the lab level. It has succeeded in producing credible data that make physical sense, match the well established lower frequency data, and extend reasonably into the higher frequency domain. A procedure has been identified for use at the lab level and beyond. Measurements with the lab system extending into a lower frequency range with canonical objects and also numerous UXO have been completed and presented to an international forum.

TRANSITION: The project intends to transition through to the Environmental Security Technology Certification Program (ESTCP). Also, integration in basic research effort of industrial partner with wide experience in developing innovative instruments, followed by field testing, application, and ultimately commercial distribution.

PROJECT SUMMARY

PROJECT TITLE & ID: Statistical Signal Processing with Physics-Based Models: Multi-Sensor UXO Detection and Identification; CU-1123

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Leslie M. Collins; Duke University – Durham, NC

FY 2001 FUNDS: $295K

DESCRIPTION: Several sensor modalities are currently being explored for the detection and identification of surface and buried unexploded ordnance (UXO). These include electromagnetic induction (EMI), magnetometers, radar, and seismic sensors. These sensors experience little difficulty detecting the UXO, thus detection does not create the bottleneck that results in the high cost of remediating sites. The primary contributor to the costs and time associated with remediating a UXO contaminated site is the high false-alarm rate associated with each of the sensors when operated individually. In this project, the team will investigate the phenomenological aspects of the UXO detection, location, and discrimination problem using EMI, radar, seismic, and magnetometer sensors. The fundamental insight garnered by characterizing the underlying physics will be transitioned into high-performance sensor fusion and signal-processing algorithms for enhanced detection, location, and discrimination of buried UXO under a wide range of environmental conditions.

The technical approach will employ synergistic research activities in modeling, signal processing, and sensor fusion. The researchers will perform phenomenological modeling of wave propagation and scattering for ultra-wideband (UWB) radar, seismic, and EMI sensors. The phenomenological studies will be performed in collaboration with SERDP-supported sensor-development programs underway in these areas (at NRL, ARL, and BBN). The previously developed models will be extended to allow arbitrary numbers of soil layers, arbitrary target shape and orientation, and to accurately account for all interactions. The use of these models will quantify the target types, depths, and soil conditions for which radar is an appropriate sensor. These models of the wave physics, coupled with models of target, clutter, and environmental uncertainties, will be incorporated into a statistical signal processing framework, thus novel, state-of-the-art optimal detection and identification algorithms will be developed for each sensor. Bayesian algorithms, which provide the optimal solution to detection and identification problems, will be investigated along with an algorithm based on a Hidden Markov Model formulation which is specifically suited for classification using data from multiple aspect angles. Finally, the researchers will develop sensor-fusion techniques that simultaneously exploit the richness and diversity of the phenomenology underlying multiple sensor modalities. Again, both Bayesian and Hidden Markov Model algorithms will be investigated. In all cases, the algorithms that are developed will be tested on data collected using sensor systems also under SERDP support, such as the BBN seismic sensor, Naval Research Laboratory (NRL)'s Multi-Sesnor Towed Array Detection System (MTADS), the Air Force Research Laboratory (ARL) Boom-SAR, and Geophex's GEM-3 EMI sensor.

BENEFIT: The goal of this project is to develop algorithms that substantially reduce false alarm rates associated with individual sensors, and that optimally combine information across sensors to further reduce the false alarm rate. Such reductions would dramatically decrease the time required to remediate Formerly Used Defense Sites (FUDS) and Base Realignment And Closure (BRAC) sites, thus decreasing the associated costs. One of the principal reasons for organizing cooperative agreements with ARL, NRL, and BBN is to assure the models and algorithms developed under the proposed research are transitioned as quickly as possible to the users in the field. It is felt that the collaborative relations will allow the researchers to tailor project developments such that they are of use to practical systems. Moreover, these organizations, which are responsible for hardware design and measurement campaigns, will gain insight from the phenomenological models to assure that the systems are designed and deployed in the most salutary fashion. After each milestone is completed, the attendant software will be released to SERDP for all SERDP contractors to use.

ACCOMPLISHMENTS: Phenomenological models have been developed and used to predict electromagnetic induction, magnetometer, and radar responses to arbitrary ordnance objects and representative clutter items. The team verified the accuracy of the models by comparing model predictions to data gathered in the field with the various sensors and thus illustrated that these models can be used to develop and train statistical signal processing algorithms. By exploiting the physics of target and clutter sensor profiles and the environmental uncertainties with enhanced signal processing for each sensor, clutter objects likely to cause false alarms can now be identified. Actual data collected by the Army Research Lab has been compared with the Duke team's representation using the Method of Moments code to more accurately predict buried general objects and orientations. An improved ability to accurately model real UXO in complex and realistic environments has been successfully demonstrated. Development of sensor-fusion techniques can simultaneously exploit richness and diversity of the phenomenology underlying multiple sensors. Data fusion techniques were applied to MTADS field data measured during the Jefferson Proving Ground-IV experiment. Improvements in the probability of detecting UXO versus a false positive have been made. Collectively, these modeling, statistical processing and sensor fusion techniques have resulted in significant performance improvements over those obtained by previous non-statistical techniques. Through a series of comparisons of sensor-based algorithms, output of statistical algorithms, and ground truth, analysts can now better discriminate UXO from scrap metal and other false positive artifacts. These efforts culminated in the receipt of SERDP's Cleanup Project of the Year for FY 2000.

TRANSITION: The project intends to transition cooperative developments. These include organized cooperative agreements with ARL, NRL, and BBN.

PROJECT SUMMARY

PROJECT TITLE & ID: An Innovative Passive Barrier System Using Membrane-Delivered Hydrogen Gas for the Bioremediation of Chlorinated Aliphatic Compounds; CU-1124

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Michael Semmens; University of Minnesota – Minneapolis, MN

FY 2001 FUNDS: $445K

DESCRIPTION: The objective of this project is to examine the gas transfer behavior and performance of hollow fiber membrane curtains that are installed as passive barriers. The proposed research will assess the suitability and effectiveness of the membrane for delivering hydrogen (H_2) to accelerate the in situ remediation of chlorinated organic compounds like trichloroethene and perchloroethene.

The proposed research will investigate the behavior of the membranes in a systematic way to determine what factors control the overall remediation process. These tasks include: (1) gas dissolution behavior of membranes, (2) impact of gas composition changes and condensation, (3) impact of biofilm growth on gas transfer, (4) evaluation of solvent transformation, (5) mathematical model development, and (6) pilot reactor studies.

The risks involved in this process include the following. (1) The membranes may not transfer H_2 fast enough when the groundwater is moving so slowly. (2) The membranes may foul and their gas transfer performance may be lost. (3) Methanogens may exploit the high local H_2 partial pressure and grow preferentially. (4) Most of the H_2 will be used to form methane gas which could accumulate locally and impede effective bioremediation by halorespirers. (5) The accumulation of locally high concentrations of methane and H_2 are of concern, since both H_2 and methane are flammable gases. (6) The accumulation of excessive biomass locally could cause a loss of permeability and a poor flow distribution through the affected site. (7) The installation process may damage the membranes and render them ineffective.

BENEFIT: This proposal specifically responds to a SERDP statement of need with the overall goal of developing an innovative passive barrier remediation technology that will reduce the costs and risks associated with contaminated site cleanup. The proposed research will characterize the performance of a novel passive barrier that relies on the use of an innovative membrane technology for the controlled dissolution of H_2. The research will employ special woven hollow-fiber membranes for the passive dissolution of H_2 in order to accelerate the in situ bioremediation of groundwater contaminated with chlorinated compounds. The hollow fiber membrane curtain can act as both a gas supply and a biofilm support. These modules can be designed to provide a large surface area for gas transfer while presenting minimal hydraulic resistance to flow. Modules of woven fibers can be installed using trench technologies and placed to create a flow-through passive barrier that is oriented normally to the direction of groundwater flow. In this way the membrane curtain provides passive gasification of the groundwater flow without the need for pumped wells, gates, or other forms of flow modification.

Passive barrier remediation systems are an attractive treatment option for the transformation of contaminated groundwater. H_2 appears to be an effective electron donor for the biodegradation of halogenated aliphatics when it is sufficiently bioavailable. However, it is difficult to provide sufficient H_2 to organisms due to its low solubility. Gas permeable membranes, used as a passive treatment barrier, could be used to provide H_2 as an electron donor for in situ bioremediation. This method of H_2 delivery would be expected to provide controlled levels of bioavailable H_2 that should provide the same benefits as cathodically derived H_2, without the associated problems.

This SERDP funded research will prove the technical feasibility of using membranes for H_2 delivery to contaminated groundwaters. In addition, the project will yield the engineering data required to complete a cost analysis and transition the membrane-module remediation system technology into field scale application.

ACCOMPLISHMENTS: In FY00, experimentation commenced following design and modeling work in 1999. The first membrane fouling studies were conducted to determine if iron sulfide deposits on the membrane surface impede gas transfer. Initial observations suggest that the process is reversible and that an increase in the oxidation-reduction potential can restore the transfer capacity. Experiments were conducted to characterize the change in the gas transfer resistance of the membrane as a function of the mass of iron sulfide precipitated per unit area of membrane. In addition, experiments were performed to assess the influence of pH on the character of the precipitate and H_2 transfer. Analytical methods for future biological experiments have been developed. Experiments have been conducted using the semi-batch reactor system. Two columns have been packed with Cape Canaveral aquifer material under anaerobic conditions, and they are being operated in continuous flow with a synthetic groundwater media. Tracer studies have been conducted to characterize hydraulic residence time, reactor dispersion and the apparent porosity of the media in the columns. A computer model has been developed to simulate PCE degradation in the H_2-fed soil column reactors. The utility of the model will be to develop hypotheses and interpret the experimental data. Membrane modules that are suitable for installation in wells have been designed and manufactured with both the reinforced silicone coated fiber and the more fragile polyolefin membranes.

TRANSITION: The project intends to transition to the user community including, Porous Media, Minntech Corp. and Membran Corp. The project intends to select a site within DoD for field demonstration/validation.

PROJECT SUMMARY

PROJECT TITLE & ID: Influence of Groundwater Constituents on Longevity of Iron-Based Permeable Barriers; CU-1125

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. A. Lynn Roberts; The Johns Hopkins University – Baltimore, MD

FY 2001 FUNDS: $202K

DESCRIPTION: This project investigates factors which may limit the longevity of iron-based permeable barriers used for in situ treatment of organic- or metal-contaminated groundwaters. This will be accomplished by examining the long-term performance of laboratory columns packed with a porous medium containing zero-valent metal solids through which simulated groundwater of differing compositions is passed, by examining the influence of eluent composition and time on the evolving composition of the solid surfaces, and by monitoring the electrochemical characterization of the surfaces after varying times of exposure. Particular emphasis is placed on developing new approaches for "real-time" monitoring of changes in system performance through a novel electrochemical probe that can be installed in situ in pilot - or full-scale applications.

The principal technical objectives are to evaluate the impact of groundwater composition on the long-term performance of zero-valent iron (Fe) barriers and to develop a prototypic electrochemical probe for monitoring reactivity changes at either the field or laboratory scale. This project intends to conduct an integrated research program to meet the following specific objectives:

- to understand the effects of groundwater chemistry on long-term barrier performance, including delineation of the impacts of chemical reactivity changes and alterations in transport properties;
- to develop an electrochemical probe that can be used to continuously assess the ongoing performance of a reactive barrier, either in laboratory columns or in situ in the field;
- to develop a fundamental understanding of the causes of alterations in reactivity through studying its relationship to the changing composition of the iron surface;
- to incorporate the results of these studies into a set of guidelines that can be used to predict the impact of the above factors on reactive barrier performance.

BENEFIT: The major output of this work will be basic research: first and foremost, an improved understanding of the impact of the aqueous chemistry on the longevity of iron, both from the perspective of "aging" and also from clogging. This project should provide a fundamental understanding of important issues dictating barrier longevity, allowing improved assessment of life cycle costs. The project team will use the results to design guidelines that outline reasonable "safety factors" concerning assumed permeable reactive barrier residence times as a function of design life of the barrier. Overall, the results of this work will allow better evaluation of the tradeoff between construction costs (e.g., barrier thickness) and system longevity. The understanding and tools developed through this effort will be directly relevant to users who apply permeable iron-barrier technology for treatment of chlorinated solvents or explosives at DoD/DOE sites. The electrochemical probe to be developed through this work has considerable promise for rapid implementation as a tool for monitoring reactivity changes in full-scale applications.

ACCOMPLISHMENTS: In FY00, this project progressed in several different areas. Three poster presentations, one oral presentation, and two invited seminars of the preliminary results of this work have been made.

- ***Column Studies.*** The initial 6 iron columns, which have now completed approximately two years of operation, continued to be monitored. Results indicated significant losses in reactivity initially and more gradual losses with time. In particular, the final step in the reaction sequence seems to be slowing over time more rapidly than the other steps. Exposure to water, continuous exposure to chlorinated hydrocarbons, exposure to high concentrations of sodium bicarbonate, exposure to silica, and exposure to natural organic matter caused inhibitory effects. Four additional columns were initiated and equipped with electrochemical probes to determine reactivity in the presence of either calcium carbonate or sodium bicarbonate. Data are presently being collected for open circuit potential, electrochemical potential noise, and impedance spectra from the four new columns. Analysis of these data is under way.

- ***Conservative Tracer Experiments.*** Tracer studies conducted with tritiated water revealed significant changes in the transport properties over time. Fitting of the data with a "single domain" model revealed that the dispersivity increased over time, and the computed "saturation level" (which includes the effect of mineral precipitates as well as gas phases that accumulate over time) decreased. The increased dispersivity and the "tailing" of the breakthrough curves that is becoming more pronounced over time suggest that the flow becomes less uniform through the porous medium as mineral precipitates and gas bubbles accumulate; zones of "short circuiting" and of "immobile fluid" are developing. The data is now being fit to a more complex (but more physically realistic) "two domain" model to account for such effects. Although these changes in transport parameters are significant, their magnitude is sufficiently small that the net effect on reactive barrier design would be minor at typical groundwater flow velocities.

- ***Surface Characterization.*** Auger analyses of "virgin" iron particles have been conducted. Micro Raman analyses revealed the existence of goethite and magnetite near the column inlet; at greater distance within the column, "green rust" mineral phases appeared. Additional micro Raman studies are planned for January of 2001. Different corrosion behaviors have been observed based on the substance being fed to the column. Using argon depth profiling, the surface layer thickness and composition will be monitored over time during the coming year. Separate experiments have also been initiated to examine the influence of iron surface composition on reactivity.

TRANSITION: The project intends to transition through the Environmental Security Technology Certification Program (ESTCP), Air Force Research Laboratory (AFRL), Air Force Center for Environmental Excellence (AFCEE), EnviroMetal Technologies, Inc., and the Remediation Technologies and Development Forum Permeable Barriers Working Group.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Effective Aerobic Cometabolic Systems for the In-Situ Transformation of Problematic Chlorinated Solvent Mixtures; CU-1127

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Lewis Semprini; Oregon State University – Corvallis, OR

FY 2001 FUNDS: $172K

DESCRIPTION: The goal of the proposed research is to demonstrate the potential of using propane and butane-utilizing microorganisms to transform problematic Chlorinated Aliphatic Hydrocarbons (CAH) mixtures. The demonstration will be aimed towards creating in situ bioreactive passive barriers in contaminated aquifers. Oregon State University research with microorganisms stimulated on propane or butane has demonstrated the potential for transforming a broad range of CAH mixtures that have been problematic with other cometabolic substrates. Microcosm studies conducted with subsurface solids and groundwater from contaminated Department of Defense (DoD) sites, however, have shown that propane and butane-utilizers are often absent in the subsurface, or have long lag periods before effective stimulation is achieved. Thus the implementation of effective in situ treatment systems at many sites will likely require bioaugmentation. The proposed work will demonstrate effective methods to create passive treatment barriers through both bioaugmentation and the use of a subsurface delivery system. Bioaugmentation will serve only to add effective propane or butane-utilizers to the treatment zone. Microbial growth and maintenance for effective cometabolic treatment will be achieved through propane or butane addition to the subsurface. In addition, the project will explore the use of mixed cometabolic substrates for the treatment of problematic CAH mixtures.

The technical approach for this project will consists of four components: (1) Laboratory studies to select the bioaugmentation approach and to develop kinetic information for single substrate (propane or butane) and mixed substrate addition (propane and phenol, for example) for the transformation of CAH mixtures. (2) Explore molecular probe methods for tracking the added organisms in laboratory and field studies. (3) Field demonstrations to evaluate the bioaugmentation approach and to determine the effectiveness in treating problematic mixtures of 1,1,1-TCA, 1,1-DCE, and TCE using propane or butane as a single cometabolic substrate, and mixed cometabolic substrates, propane or butane with phenol or toluene, in the latter stages of the field tests. (4) Modeling evaluations of the laboratory studies and the field studies, including simulations to aid in the design of the field demonstration tests.

BENEFIT: The primary benefit from the outcome of this project will be a field documented in situ cometabolic process that transforms problematic mixtures of CAH's. This technology will be a new in-situ application of aerobic cometabolism for complex CAH mixtures. In addition, a bioaugmentation methodology for in-situ cometabolism will be developed to be possibly used as a remediation alternative for sites where natural attenuation or biostimulation will not work. This technology may be used a passive process that can be applied in deep aquifers or in a stratigraphy with multiple clay lenses. Other products from this research include developing an approach for establishing effective microbial communities for in-situ cometabolic treatment, modification to the Cometabolism Transport Model, assessment of community structure changes with bioaugmentation and cometabolic transformation, and specific probe method development for propane and butane bioaugmentation cultures.

ACCOMPLISHMENTS: Progress in the kinetic studies with the bioaugmentation enrichment culture work has focused on growing the enrichment culture under conditions that will be used for the field bioaugmentation. Cells grown on butane were harvested then used in microcosm tests containing aquifer solids and groundwater from the Moffett Field Test Site. Rapid uptake of butane was observed within 5 days of introducing the enrichment into the microcosms, and 1,1,1-TCA transformation occurred upon stimulation on butane. With repeated additions of butane, the rate of 1,1,1-TCA transformation increased, and numerous additions of 1,1,1-TCA were transformed with a single addition of butane. Results of these tests have been modeled with a non-steady-state model for the growth of the butane-utilizers and the cometabolism of 1,1,1-TCA. Kinetic parameters derived from the model indicate that if similar rates of 1,1,1-TCA transformation are achieved in the treatment zone effective remediation of 1,1,1-TCA would be observed. Microcosm studies evaluating the bioaugmentation dose and the ability to cometabolize 1,1-dichloroethylene (1,1-DCE) have also been conducted. Bioaugmentation microcosms rapidly consumed butane and transformed 1,1-DCE, while in the non-augmented biostimulation was much slower, but butane was eventually consumed and 1,1-DCE was slowly transformed. In microcosms bioaugmented in the absence of butane, butane was eventually consumed and 1,1-DCE was transformed. The results show bioaugmentation in the presence of butane resulted in the most effective and reproducible treatment of 1,1-DCE. Results of these microcosm studies have been successfully modeled using a non-steady-state model that includes growth on butane, transformation product toxicity, and competitive inhibition between butane and 1,1-DCE. Independently derived kinetic parameters, determined in previous kinetic studies performed in nutrient media and with resting cells, resulted in good fits to the experimental data.

Progress in microbial characterization and probe development work continues on characterization of the enrichment culture that is to be augmented at Moffett Field. A clone library containing 16S rDNA genes from the augmentation culture has been created. Restriction digest analysis (HaeIII) of the 88 colonies revealed 35 distinct banding patterns with 16 patterns repeated two or more times. An internal primer, 700R, was used to sequence a representative clone from each of the 16 groups. Visual inspection of the augmentation culture using DAPI staining and fluorescence microscopy found only two or three dominant morphologies. Molecular analysis suggests the augmentation culture is more complex than was apparent from visual inspection. Comparison of the obtained sequences to the GenBank database identified four major species of organisms present in the augmentation culture. One representative from each of the four microbial groups was fully sequenced. The sequence information was then used to design rRNA probes for each of the four fully-sequenced clones. Sequence information obtained from GenBank for organisms closely related to the four clones and from organisms of greater evolutionary distance was used in the probe design in order to create probes with a high degree of specificity for the organisms present in the augmentation culture. The probes have been synthesized and are ready for use. In situ hybridization of the probes to the augmentation culture as well as to any isolates obtained from the isolation culture is the next step in molecular characterization of the augmentation culture. Simulations were also conducted using 16S rDNA sequences from organisms in the GenBank database that closely resembled the sequenced clones to estimate the specificity or uniqueness of the fragment patterns for each clone/enzyme pair. Initial indications are that three of the four organism that were well represented in the clone library are also present in high numbers in the microcosm samples. Isolation attempts and T-RFLP analyses of isolates and microcosms are ongoing.

TRANSITION: The project intends to transition to the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: Nonintrusive Characterization of Dense Nonaqueous Phase Liquids Using Short-Lived Radiotracers in Partioning Interwell Tracer Tests; CU-1128

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Phillip A. Gauglitz; Pacific Northwest National Laboratory – Richland, WA

FY 2001 FUNDS: $17K

DESCRIPTION: The objective of the proposed research is to develop partitioning interwell tracer testing using short-lived radioisotopic tracers as an effective characterization technique for Dense Nonaqueous Phase Liquids (DNAPL) in the subsurface. This technique can be viewed as the next evolution in partitioning tracer testing and offers significant benefits over currently available technologies. By injecting conservative and partitioning short-lived radioisotopic tracers into the subsurface and continuously measuring their presence in monitoring wells with moveable downhole detectors, the location and amount of DNAPL can be measured to a much greater extent than can now be achieved by any other method.

The technical approach for this project is to develop the radiochemical techniques for making tagged tracers together with assembling suitable detectors. After the field prototype has been tested, the tracers and sensors will be used in a field application to further develop the method. The field testing will be guided by detailed fluid flow modeling, as will the interpretation of the field results. The tasks for this project are: (1) Detector and Logging System Development, (2) Tracer Selection and Radiochemistry Techniques, (3) Laboratory Testing, (4) Pre-Test Modeling and Field Test Planning, (5) Field Testing, (6) Inverse Modeling (Data Analysis), and (7) Development of a Guidance Document.

BENEFIT: The proposed research will develop an innovative, nonintrusive radiotracer methodology for reliably detecting, quantifying, and determining the horizontal and vertical extent of non-aqueous phase liquids (NAPLs) in the subsurface environment. The desired information will be available in an easily interpretable format and will provide the ability to detect and delineate subsurface NAPLs to an extent beyond any existing technology. This additional information will substantially improve risk assessment, remedial system design, optimization of remedial operations, and verification for site closure.

The proposed research will lead to a cost-effective technique for more precisely locating DNAPL sources, estimating the mass, and monitoring the transport and/or reduction of the mass over time, which are critical aspects of cost-effective cleanup. It is anticipated that the costs to implement the developed technology will be comparable to those of conventional partitioning interwell tracer tests, with significantly more characterization information achieved.

ACCOMPLISHMENTS: The detector and logging systems have been selected and assembled and await final programming and testing based on the actual field conditions that will be encountered. Simulated field tests are being planned. Test design refinements and regulatory concerns have led to the choice of Br-82 as the radioisotope of interest; this will be attached to the alcohols chosen for testing. Partition coefficients have been established for the brominated alcohols chosen for use as tracers. Extensive testing has been performed of the depth of measurement of the radioisotopes in a saturated soil. These results have been incorporated into software that allows an integrated measurement of the amount of radionuclide flowing past a well.

TRANSITION: The project intends to transition the complete package for deployment in saturated and/or unsaturated DNAPL zones within DoD sites. The technology will be deployable by site personnel or service companies. Interest has been expressed by Current Environmental Solutions, Inc. and others.

PROJECT SUMMARY

PROJECT TITLE & ID: Biological Assessment for Characterizing Contaminant Risk at the Genetic-, Individual-, and Population-Level; CU-1129

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Todd Stephen Bridges; U.S. Army Corps of Engineers Engineer Research and Development Center, Environmental Laboratory – Vicksburg, MS

FY 2001 FUNDS: $424K

DESCRIPTION: The objective of this project is to develop a suite of technically defensible assays that can be effectively used in regulatory programs to quantify the ecological risk of contaminated sediments at the molecular-, individual-, and population-level. Researchers will quantify the biological/ecological meaning of genetic responses, collected using genosensors, by way of comparison to whole-organism assessments of toxicity and modeled population-level impacts. Dose-response information will be simultaneously generated using genosensors and whole-organism bioassays for such military-relevant compounds as explosives trinitrotoluene (TNT), cyclotrimethylenetrinitramine (RDX), cyclotetramethylenetetranitramine (HMX), other organics such as polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbon (PAH), and metals such as lead (Pb).

During the first phase of this project, (1) sediments will be spiked with single military-relevant compounds (i.e., explosives and other organics) and mixtures at a range of concentrations, (2) sediment-dwelling organisms will be exposed to these contaminated sediments, (3) the sediments and organisms will be screened for the presence of genetic markers using developed genosensors, and (4) whole-organism effects on survival, growth and reproductive endpoints will be measured. Four sediment-dwelling organisms will be used in this project that are currently being used by the Environmental Protection Agency (EPA) and the Corps to develop chronic, sublethal sediment bioassays for national regulatory programs. Two of the species occur in marine habitats (Neanthes arenaceodentata and Leptocheirus plumulosus) and two of the species are found in freshwater habitats (Hyalella azteca and Chironomus tentans). Impacts at the population-level will be projected using population models developed for bioassay organisms during the course of this study. By simultaneously measuring biological responses at three distinct levels of biological organization (i.e., genes, whole organisms, populations) the team of researchers will have the ability to effectively test the reliability of estimating potential risk at higher levels of organization (e.g., ecosystems) using information that can be quickly and inexpensively collected at lower levels of organization (i.e., the level of genes).

During the second phase of study, the bioassay suite will be tested using naturally contaminated sediment containing even more complex mixtures of military-relevant and conventional contaminants. The comparisons made among the endpoints at each level of organization using field collected sediments ranging in degree of contamination will allow researchers to test how robust their predictions will be under a regulatory use scenario.

BENEFIT: Currently there is a lack of defensible methods to measure and assess ecosystem responses to insults by Department of Defense (DoD) relevant contaminants. Large uncertainties surround current cleanup goals for military-unique contaminants (MUC) and estimates of environmental risk resulting from exposure to MUCs. The large assumptions and extrapolations required by current approaches necessitates the use of large safety/uncertainty factors which lead to very conservative cleanup goals that are very expensive to obtain with current cleanup technologies. This project will provide tangible benefits to DoD cleanup efforts by reducing the driving uncertainties in the estimation of risk in MUC contaminated sediments, namely, (1) contaminant bioavailability, (2) the toxicity of MUCs, (3) the toxicity of complex MUC mixtures, and (4) extrapolating to higher order effects (e.g., population-level impacts). The methods and data generated during this project will improve DoD's capability to defensibly define risk to aquatic organisms exposed to MUCs and to set reasonable cleanup levels that are based on the potential for toxicity at multiple levels of biological organization. Given the number of contaminated DoD/DOE sites (17,000), the potential for remedial cost avoidance is considerable.

ACCOMPLISHMENTS: More than 30 short and long-term toxicity/bioaccumulation experiments were successfully completed during the first two years of this project with RDX, HMX, TNT, TNB and 2,4-DANT. Chemical analysis of sediment and tissue samples from these experiments was performed to provide accurate interpretation of the toxicity data. Several experiments were conducted to define the toxicity of mixtures of TNT and its degradation products. In the case of water-only exposures, response additivity appears to be a suitable model for describing the nature of the toxicological interaction. Results demonstrated that juveniles were more sensitive than adult organisms and that the toxicological effects of TNT, TNB, and DANT were manifested through decreases in survival. In another study addressing the toxicity of TNT and three of its metabolites (TNB, 2-ADNT, 2,4-DANT), the magnitude of the lethal effects of TNT, TNB and 2-ADNT was similar; however, the lethal effects of 2,4-DANT were expressed at much higher concentrations. The nature of the chemical interaction among these four nitroaromatic compounds was examined in two mixture experiments. The results strongly suggested response additivity of mixtures of nitroaromatic compounds. Effects on survival of three aromatic munitions compounds (2,4, 6-trinitrotoluene (TNT), 2-4-diamino-6-nitrotoluene (DANT), 2-amino-4,6-dinitrotoluene (2-ADNT)) and lead were assessed in another study. Emergent juveniles were found to be more sensitive to TNT than the other compounds. Survival of organisms exposed to lead was significantly lower in the treatments compared to the control. No mortality was observed in exposures to DANT. In the 2-ADNT exposures, significant differences in survival were observed between the control and the 40.6 and 50.7 uM treatments. Future experiments will include 96h exposures to 4-ADNT and exposures to nitroaromatic compounds following pretreatment with antioxidants and enzymatic inducers to target specific mechanisms of toxicity in gene-based endpoints. Work to isolate and identify explosives-responsive genes using differential display continues. Differential display using randomly chosen primers was found to be unreliable because it resulted in unreproducible banding patterns. A different approach, Restriction Fragment Differential Display (RFDD), has resulted in very reproducible banding patterns. Work is currently underway using RFDD to isolate explosive responsive genes from Neanthes. Confirmed products will be biomarkers to detect HMX or TNT toxicity.

TRANSITION: The project intends to transition to the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: Evaluation of Performance and Longevity at DoD Permeable Reactive Barrier Sites; CU-1140

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Chuck Reeter; Naval Facilities Engineering Services Center – Port Hueneme, CA

FY 2001 FUNDS: $250K

DESCRIPTION: Site-specific conditions should be the ultimate factor in designing a permeable reactive barrier (PRB) remediation solution, and the site performance and compliance monitoring plan should evaluate its operating effectiveness. Because the main goal of installation cleanup is to ensure that contamination is remediated and ultimately prevented from progressing further downgradient of the site, monitoring is needed to evaluate the capture and treatment efficiency of the PRB configuration. Since all current PRBs have somewhat different design configurations, it is important to evaluate selected sites using a consistent approach. The purpose of this Department of Defense (DoD) SERDP/ESTCP project and its two companion projects with the Department of Energy (DOE) and the Environmental Protection Agency (EPA) is to achieve combined Federal agency coordination in addressing these various performance and longevity issues at specific Permeable Reactive Barrier (PRB) projects. The DoD, EPA, and DOE projects are being executed simultaneously for a leveraged effort that will achieve maximum coordination to minimize duplication and to ensure that the most cost-effective measures will be implemented. Project coordination will ensure that data collected from each site are comparable, while allowing each agency to focus on its unique needs.

This project is intended to specifically focus on the DoD sites, only. The EPA and DOE will provide separate funding for their selected sites. Similar to the DOE and EPA projects, the DoD project approach will be conducted using the following tasks: (1) Field Monitoring Survey and Site Selection, (2) Performance Sampling at Selected PRB Sites, and (3) Performance Data Evaluation.

BENEFIT: It is estimated that potentially 500-1,000 DoD sites could use the PRB technology. Using actual site specific data from cost analyses performed at one Navy location, the results can typically represent most DoD sites. At Naval Air Station (NAS) Moffett Field, it would cost about $9 Million (M) to remediate the site by using a full-scale PRB over a 50-year period. Conversely, it would cost about $33M over a 50-year period using the groundwater pump-and-treat method. Specifically for Moffett, over the long term, the cost savings ratio of using the PRB technology over pump-and-treat can be as much as 4 times. Overall, it is estimated that the Moffett site can save about $24M in contaminant plume remediation costs. It is reasonable to conclude that over the long term, billions of dollars could be saved at hundreds of chlorinated compound contaminated sites where the PRB technology can potentially be applied.

ACCOMPLISHMENTS: In FY00, the project completed the tri-agency PRB initiative (RTDF Workgroup) information brochure, the site specific DoD PRB monitoring and sampling workplan, and the modeling performance report. Sampling and coring at Lowry AFB PRB site commenced followed by colloidal borescope flow testing. Sampling and colloidal borescope flow testing also took place at Dover AFB. Two jointly sponsored PRB training classes were conducted. The final Permeable Reactive Barriers Survey Report and the final report on Monitoring Strategy for PRBs at DoD sites were issued. Longevity (bench) evaluations of groundwater, hydraulic and geochemcial modeling, and evaluation of data continue.

TRANSITION: The project intends to transition through the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: In-Situ Bioreduction and Removal of Ammonium Perchlorate; CU-1162

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Coates; Southern Illinois University – Carbondale, IL

FY 2001 FUNDS: $120K

DESCRIPTION: This project will provide a better understanding of the microbiology involved in microbial perchlorate reduction and removal. The factors controlling the applicability of microorganisms to the in-situ treatment of ammonium perchlorate contamination of natural water supplies will be determined. In addition, this work will assist in the development of protocols and molecular tools required for the modeling and application of in-situ bioremediation strategies to treat perchlorate contamination in the environment.

The objectives of this project will be addressed under the following hypotheses.

Hypothesis 1. Perchlorate-reducing bacteria are ubiquitous and are indigenous in perchlorate contaminated environments. The perchlorate-reducing population in the samples will initially be enumerated by most probable number counts (MPN) with acetate as the electron donor. In addition, the predominant indigenous perchlorate-reducing bacteria (ClRB) in the samples will be determined by Polymerase Chain Reaction (PCR) amplification with specific primers followed by Denaturing Gradient Gel Electrophoresis (DGGE) analysis and sequencing.

Hypothesis 2. All perchlorate-reducing bacteria contain a conserved chlorite dismutase enzyme. In order to evaluate this hypothesis the researchers will use the purified chlorite dismutase enzyme from the ClRB, Dechlorimonas agitatus strain CKB, to determine the N-terminal sequence, and develop a specific molecular probe to the gene that codes for this enzyme. Following sequence analysis of the gene, universal probes for ClRB will be constructed.

Hypothesis 3. Indigenous microbial perchlorate reduction can be easily stimulated in contaminated environments. As all ClRB isolated to date are alternatively able to utilize nitrate as an electron acceptor, the addition of nitrate to the environment should result in an increase in the perchlorate-reducing microbial population. Sediment samples will be enriched under anaerobic conditions by nitrate and acetate addition and tested for stimulation of perchlorate reduction.

Hypothesis 4. The stimulated perchlorate reducing population can remove perchlorate concentrations to levels significantly lower than 18 ug/L. Several of the phylogenetically diverse ClRB isolates in the projects laboratory cultures will be selected and grown individually in continuous culture in a chemostat. Once steady state is achieved, temperature, pH, ion concentration, dissolved oxygen concentration, and perchlorate concentration will be varied individually. Final perchlorate concentrations achieved by each organism under all conditions will be determined and compared.

Hypothesis 5. The rate of microbial perchlorate reduction will be affected by the environmental conditions. To determine the controlling factors of perchlorate reduction, samples enriched with acetate and nitrate will be used. Specific perchlorate-reducing activity will be determined in subsamples under a range of redox, pH, and temperature values, as well as ionic strength, and perchlorate concentrations to determine optimum conditions for perchlorate reduction. In addition, the effect of the presence of alternative electron acceptors will also be determined.

Hypothesis 6. The stimulated perchlorate-reducing population will also enhance biodegradation of co-contaminating organics. Degradation of 14-C-labeled hydrocarbons by perchlorate-reducing enriched samples will be determined by monitoring 14-CO2 production over time.

BENEFIT: Results from these studies will result in a better understanding of the microbiology involved in perchlorate reduction and the factors controlling the activity of these organisms. These studies will also allow the development of a molecular probe which will be specific for all perchlorate-reducing bacteria. Such a probe can be used for predictive determinations of the success of a biological in-situ treatment process and also as a monitoring tool for intrinsic or enhanced bioremediative efforts. Finally this study will identify the potential of a stimulated perchlorate-reducing population.

ACCOMPLISHMENTS: Hypothesis-specific accomplishments follow.

Hypothesis 1. Based on phylogenetic characterizations performed on more than twenty isolates of (per)chlorate-reducing bacteria (ClRB), it has been determined that the predominant group of ClRB reside in the beta subclass of the Proteobacteria. PCR primers have been designed and tested that are specific to groups of ClRB. Using these primer sets, one or more of these ClRB types in perchlorate-contaminated environments from Indian Head have been detected and MPN series from these sites have been established. These primers were also used to screen a number of other environmental samples (petroleum-contaminated sites, wastetreatment sludge, swine waste lagoons, etc) and detected the presence of ClRB in all of these sites, including pristine environments and sites in the Antarctic. Thus, it has been established that perchlorate-reducing bacteria are indeed ubiquitous in the environment but are also indigenous to perchlorate-contaminated environments. Methods developed here will continue to be used to screen all of the environmental samples that will be collected during the course of this project.

Hypothesis 2. Because of the phylogenetic diversity of ClRB isolated to date, it is not possible to design PCR primer sets specific to all ClRB using 16S rDNA sequence data. A more attractive target for a universal ClRB probe is the chlorite dismutase enzyme which is responsible for the conversion of chlorite to chloride and molecular oxygen. In support of this hypothesis, the chlorite dismutase enzyme has been isolated from ClRB Dechloromonas agitata strain CKB. At each step of the purification protocol, fractions collected from the various columns were assayed for specific activity of chlorite dismutation using a novel colorimetric micro enzymatic assay for chlorite which was recently developed by this research group (patent pending) and also by following O2 production using an O2 electrode. The N-terminal sequence of the purified enzyme was then determined by Commonwealth Biological Inc., VA. Using the N-terminal amino acid sequence information, an oligonucleotide probe was designed for the chlorite dismutase gene using appropriate degeneracies for the third-base codon positions. This probe will be used to screen a Dechloromonas agitata strain CKB genomic library recently constructed in E. coli in order to isolate and characterize the gene encoding chlorite dismutase. Once the gene that encodes for the chlorite dismutase is identified and confirmed, a probe will be designed that is specific to this gene that can be used to identify these organisms in the environment regardless of their phylogenetic affiliation.

TRANSITION: All results produced during the course of this project will be published in peer reviewed journals and be accessible to the public. Project researchers are in the process of developing a World Wide Web page devoted to ongoing research in the area of microbial perchlorate reduction in their respective laboratories. The results, tools, and techniques produced as part of the above proposed research will be documented at this site. In addition, current ongoing research on the microbiology of perchlorate reduction has resulted in 4 patent applications which have attracted the interest of several biotechnological/ bioremediation companies.

PROJECT SUMMARY

PROJECT TITLE & ID: In Situ Bioremediation of Perchlorate; CU-1163

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Paul Hatzinger; Envirogen, Inc. – Lawrenceville, NJ

FY 2001 FUNDS: $303K

DESCRIPTION: The discharge of contaminated effluents during the manufacture and replacement of propellants in military missiles and rockets has resulted in substantial perchlorate contamination in groundwater in several states, including California, Utah, Texas, and Nevada. The objective of this SERDP project is to develop a biological treatment technology for the in situ remediation of perchlorate in groundwater. The experiments proposed in this effort are designed to provide a fundamental understanding of the factors promoting perchlorate degradation in subsurface environments as well as the conditions that inhibit this process. Laboratory microcosms and flow-through model aquifers with sediments and groundwater collected from perchlorate impacted sites will be used during the project.

This project intends to conduct research over several areas. These areas are highlighted below.

Task 1. Collect Aquifer Solids and Groundwater from Field Sites: Aquifer samples will be collected from known or potential perchlorate contaminated sites, including commercial remediation sites, and military sites. Ideally, aquifer solids and groundwater will be obtained from at least three field sites with different geochemical characteristics. These samples will be used in microcosm studies to represent the range of different environments that have experienced perchlorate contamination.

Task 2. Obtain Microbial Consortia and Individual Bacterial Isolates Capable of Perchlorate Degradation: The objective of this task is to isolate individual perchlorate degrading bacteria or a mixed bacterial culture from pilot and full-scale Fluidized Bed Reactor (FBR) systems that are currently reducing perchlorate in water to non-detectable levels. The resulting consortia and/or individual strains will then be used in subsequent microcosm and flow-through column experiments to evaluate the potential for bioaugmentation as an in situ remediation strategy for perchlorate.

Task 3. Identify Conditions Required for In Situ Biostimulation of Perchlorate Degradation: The objective of this task is to develop an understanding of the factors promoting perchlorate degradation in subsurface environments as well as the conditions that inhibit the process.

Task 4. Construct and Operate Pilot-Scale Model Aquifers: The most effective treatments (biostimulation and/or bioaugmentation) for perchlorate degradation in the microcosm studies will be further tested using pilot-scale flow through model aquifers.

Task 5. Biodegradation Modeling: Groundwater flow and reactive transport modeling will be conducted to verify degradation rates derived from laboratory studies and to aid design of field-scale applications. The model aquifers will be used to determine substrate (electron donor) loading rates, perchlorate reduction kinetics by natural and inoculated strains, and inhibitory concentrations of groundwater constituents such as nitrate and oxygen.

BENEFIT: The research outlined in this proposal will provide extensive information on (1) the potential for successful perchlorate remediation at subsurface sites by addition of electron donors (i.e., biostimulation); (2) the most effective electron donors to use in biostimulation efforts, and the expected concentrations and remediation kinetics achievable with these donors; (3) the possibility for successful bioaugmentation (i.e., injection of bacterial isolates) for subsurface perchlorate remediation; and (4) the probable influence of alternate electron acceptors and environmental variables on perchlorate reduction during biostimulation and/or bioaugmentation efforts. These data will provide the fundamental knowledge required for the design and implementation of pilot-scale and full-scale remediation efforts at perchlorate contaminated sites.

ACCOMPLISHMENTS: Field samples have been obtained from four perchlorate-contaminated sites: Jet Propulsion Laboratories (Pasadena, CA), Indian Head Division Naval Surface Warfare Center (Indian Head, MD), a commercial facility in the Rocky Mountains, and the Longhorne Army Ammunition Depot (Longhorne, TX).

Microcosm studies from the Jet Propulsion Laboratory (JPL) site are complete. Several electron donors including acetate, lactate, yeast extract, ethanol, and molasses rapidly stimulated perchlorate degradation by indigenous bacteria at the JPL site. Perchlorate levels were reduced from 0.31 mg/L to less than 0.005 mg/L in ten days. The results reveal the following: (1) indigenous bacteria capable of degrading perchlorate are present in the aquifer underlying JPL; (2) these bacteria can be stimulated to degrade perchlorate by the addition of several electron donors; and (3) perchlorate levels can be reduced to below current action levels through biostimulation. Additional studies showed that oxygen completely inhibits perchlorate biodegradation in JPL samples and that nitrate and nitrite are preferentially degraded as electron acceptors although whether these ions actually inhibit perchlorate degradation is unclear from the microcosm data. Perchlorate degradation by indigenous bacteria in the JPL samples declined as pH decreased below 7.0, and was completely inhibited at a pH value of 4.0. Increasing salinity also caused inhibition of perchlorate degradation in site samples. Two microbial strains capable of perchlorate degradation were isolated from the JPL site samples using enrichment and purification techniques. These isolates have not yet been identified or studied further.

Microcosm studies from two separate locations at the Indian Head (IHDIV) site and the commercial site in the Rocky Mountains are currently ongoing. Perchlorate was readily degraded in one set of subsurface samples collected from IHDIV when hydrogen gas or acetate (but not ethanol or molasses) were added as electron donors. Conversely, perchlorate degradation was not observed in a second set of subsurface samples from IHDIV after amendment with several electron donors or augmentation with a culture of exogenous perchlorate degrading bacteria. Experiments are underway to evaluate the factors inhibiting perchlorate biodegradation at this location. In samples from the Rocky Mountain site, bioaugmentation was found to reduce perchlorate levels from 60 to approximately 15 mg/L in the first 6 days. Addition of several electron donors did not stimulate perchlorate degradation by indigenous bacteria during this initial 6-day period, but results after longer incubation times are not yet available.

Data collected thus far suggest that in situ bioremediation is a promising technology for perchlorate remediation, but that the remediation approach, including the choice of electron donor, may vary by site. Initial studies also suggest that environmental conditions, including pH and salinity, may influence in situ perchlorate biodegradation.

TRANSITION: The long-term goal of this project is to develop and demonstrate a technology that can be easily transitioned to field deployment. The final report will include a section that identifies the most viable methods for field implementation based on the research findings and modeling results. At the conclusion of the SERDP studies, ESTCP or other funding will be sought to demonstrate the most promising remediation strategy in a field study, an application protocol will be prepared, and Envirogen will then commercialize and license the technology.

PROJECT SUMMARY

PROJECT TITLE & ID: In Situ Bioremediation of Perchlorate-Impacted Groundwater; CU-1164

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Evan Cox; GeoSyntec Consultants Inc. – Guelph, Ontario, Canada

FY 2001 FUNDS: $197K

DESCRIPTION: Groundwater contamination related to the production, handling and use of rocket propellants such as ammonium perchlorate has been identified as a widespread problem at Department of Defense (DoD), Department of Energy (DOE) and defense contractor facilities. Few cost-effective technologies exist for the treatment of perchlorate-contaminated groundwater. Of the technologies being evaluated, in situ bioremediation is among the most promising because it has the potential to destroy perchlorate in place rather than transferring perchlorate to another waste stream (e.g., impacted resin or brine) requiring treatment or disposal.

This research program consists of: (1) laboratory microcosm studies to evaluate the ubiquity of perchlorate-degrading bacteria in groundwater at a variety of impacted DoD, DOE and defense contractor facilities, and to assess the applicability of in situ bioremediation as a remedial technology in a variety of geochemical environments; followed by (2) small-scale field pilot testing at one of the test sites to demonstrate that perchlorate can be biodegraded under field conditions, and to generate initial design and cost data for potential technology scale-up and validation. The product of this research will be the development of a robust, reliable and cost-effective treatment technology for perchlorate-impacted groundwater at DoD, DOE and defense contractor facilities.

BENEFIT: The presence of perchlorate in drinking water supplies is a national concern that requires the timely development of robust, reliable and cost-effective treatment technologies for large volumes of groundwater. Cleanup costs for perchlorate-impacted groundwater are expected to be in the $100Ms in California alone, the cost of which may jeopardize major DoD and propulsion contractor production programs. The support of cooperative development partners such as, Aerojet General Corporation and the U.S. Navy, for the proposed research program highlights the need for development of cost-effective and environmentally-acceptable perchlorate treatment technologies.

A significant number of other federal and defense contractor facilities may benefit from the development of cost-effective in situ remediation technologies for perchlorate-impacted groundwater. For example, the Environmental Protection Agency (EPA) has identified at least 14 facilities in California, including 7 Superfund sites, where perchlorate is present in groundwater, and where groundwater remediation is likely to be required once final groundwater standards are established. The majority of these sites are rocket manufacturers and testing facilities associated with DoD and National Aeronautics & Space Administration (NASA).

ACCOMPLISHMENTS: Soil and groundwater materials have been obtained from 6 DoD and related propulsion contractor facilities. Test sites include: (1) Aerojet Superfund Site IRCTS, California, (2) Edwards Air Force Base, California, (3) U.S. Navy San Nicolas Island, California, (4) Allegany Ballistics Laboratory, West Virginia, (5) American Pacific Corporation, Nevada, (6) Boeing Alpha/Sigma Complex, California. Results to date have confirmed that perchlorate biodegrading bacteria are present at each of the first 5 test sites and that perchlorate biodegradation can be stimulated through the addition of soluble electron donors such as molasses and acetate and slow-release electron donors such as oleate. These results provide a strong indication that in situ bioremediation will be a widely applicable technology for remediation of perchlorate-impacted groundwater. Results emerging from the microcosm studies show that perchlorate biodegradation can be promoted/accelerated at each of these test sites through the addition of electron donors. However, acclimation periods and geochemical interferences (e.g., high nitrate, sulfate) are variable between sites. Two of the test sites will be selected to conduct an in-depth evaluation of the geochemical tolerance ranges of perchlorate degraders, including perchlorate concentration, pH, salinity, temperature, and presence of other electron acceptors such as nitrate and sulfate.

Microbial enumerations using MPN techniques have been initiated for each test site, and specific perchlorate degraders will be isolated from each test site in collaboration with Southern Illinois University, to assess whether the perchlorate-degrading organisms are the same or similar from each of the test sites. Geochemical tolerance testing was initiated to assess the effects of different starting perchlorate concentrations (ranging from 0.1 to 10,000 mg/L) on perchlorate reduction.

TRANSITION: Through the proposed research program, the project team expects to develop a remediation technology ready for large-scale field demonstration (via ESTCP or similar program), validation and implementation. The early tasks of the project will contribute key knowledge improving the understanding of the ubiquity of perchlorate-degrading bacteria, and the potential applicability of in situ bioremediation for perchlorate-impacted sites. The small field pilot test will, within a relatively short timeframe, provide design and cost data so that the technology can be scaled-up, validated, and transitioned within DoD, DOE and industry for full-scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Extraction Tests for Determining the Bioavailability of Metals in Soil; CU-1165

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Michael Ruby; Exponent Environmental Group – Boulder, CO

FY 2000 FUNDS: $200K

DESCRIPTION: The primary objective of the proposed project is to develop a suite of simple and easy-to-use extraction tests to predict human and ecological exposures to metals in soil. Such tests will provide inexpensive and rapid tools for establishing the bioavailability of metals in soils at hazardous waste sites. Soils used in the project will be characterized for metal species and soil parameters to provide a mechanistic basis for any differences in metals bioavailability among the samples. Therefore, results from the project will also provide an understanding of how various species of a metal may differ in bioavailability, and also how various soil properties may affect metals bioavailability and the stability of the measured bioavailability estimates.

The proposed project will be framed around specific metals (arsenic, cadmium, copper, lead, nickel, and zinc) that are cost drivers for remediation of soils at Department of Defense (DoD) sites, and will focus on the most important receptors and exposure pathways for these metals. Historically, oral exposures to humans and terrestrial receptors have dominated risk assessments. Recently, dermal exposures have become more important in human health risk assessments as the U.S. Environmental Protection Agency (EPA) adopts default dermal absorption values for some metals. As described below, an extraction technique developed by Exponent has already been demonstrated to predict human oral exposure to lead, arsenic, and other metals in soils. A research consortium founded by Exponent is currently completing validation of this method for lead, and working on validation of the method for arsenic. This project will extend application of this technique to other metals of concern (cadmium, copper, nickel, and zinc). The results of this extraction technique should also be applicable to assessing exposures of terrestrial mammals in ecological risk assessments. The project will include an evaluation of method parameters that might be modified to better predict relative bioavailability of metals in soil in different kinds of mammals (e.g., rodents vs. ruminants). A second aspect of the project will focus on assessing dermal absorption of arsenic and cadmium from soil. No studies have been conducted of dermal absorption of these metals from weathered soils. Initial studies will include animal studies and in vitro studies using human cadaver skin. After testing dermal absorption of these metals from weathered soils, development of a simple extraction test for dermal absorption will begin. For each soil tested, pore-water measurements of free metal ions will also be conducted to predict metal absorption in soil invertebrates. It is anticipated that this research will lay the groundwork for a suite of simple extraction tests that will enable the assessment of relative bioavailability of metals in soil to humans and a range of ecological receptors.

BENEFIT: Metals occur in soil as a complex mixture of solid-phase chemical compounds of varying particle size and morphology. These compounds include discrete mineral phases, coprecipitated and sorbed species associated with soil minerals or organic matter, and dissolved species that may be complexed by a variety of organic and inorganic ligands. The occurrence and relative distribution of an element among these various phases, and the physical relation between the phases and the soil, control an element's solubility, and hence, its bioavailability. A number of physical methods have been developed for evaluating metals species in soil, such as sequential extractions, x-ray diffraction, and electron microbearn techniques (e.g., scanning electron microscopy and electron microprobe), and each has its own advantages and limitations. However, given the complexity of metal mixtures in soil, it has proven quite difficult to extrapolate from information on metal speciation to defensible estimates of metals bioavailability (except for very simple systems composed of only a few pure mineral phases). As a result, the most promising simple tests for quantifying the bioavailability of metals from soil are extraction tests to measure the fraction of a metal that is soluble and available for absorption. This same conclusion has been reached by individuals studying the bioavailability of other complex mixtures in soil, including polycyclic aromatic hydrocarbons (PAH). Evaluation of metal speciation in soils by electron microprobe analysis, as well as complete characterization of soil parameters, will be used to provide mechanistic explanations for the results of the extraction tests. Once developed, these simple tests will be useful for assessing metals bioavailability during site assessment, evaluating any changes to bioavailability after remediation or restoration, and studying the long- term stability of metal species in amended soils.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: The proposed research is designed to yield a suite of simple extraction tests that are inexpensive to perform, produce reliable results, and are predictive of metals bioavailability from soil to human and ecological receptors. These tools will then be available to DoD personnel for site- specific evaluation of metals bioavailability from soil at field sites, and will result in more accurate exposure and risk estimates that are still protective of human health and the environment.

PROJECT SUMMARY

PROJECT TITLE & ID: Quantifying the Bioavailability of Toxic Metals in Soils; CU-1166

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Phil Jardine; Oak Ridge National Laboratory – Oak Ridge, TN

FY 2001 FUNDS: $445K

DESCRIPTION: The objective of this SERDP project is to investigate the relative bioavailability of the toxic metals Lead (Pb), Zinc (Zn), Copper (Cu), Cadmium (Cd), Arsenic (As), and Nickel (Ni) in soils, primarily in relation to the human health risk posed by soil ingestion which often controls the degree of cleanup required at metal-contaminated sites. Specific objectives of this investigation are to: (1) Measure changes in relative bioavailability over time in a wide range of soil types which may be encountered at DoD sites within the U.S.; (2) Develop a predictive capability to quantify toxic metal bioavailability on the basis of soil properties; and (3) Investigate the fundamental relationship between molecular-level speciation and bioavailability to enhance the understanding and predictive capability of the fate of toxic metals in soil. Following successful completion of the research project, these results will provide site managers and risk assessors with tools to make better initial estimates of site risk which can be used to prioritize site cleanups and to justify more definitive site-specific bioavailability studies such as detailed soil speciation investigations and in vivo studies.

One of the biggest challenges in investigating metal bioavailability is in selecting a measure of bioavailability. Since the bioavailability of a contaminant is often receptor dependent (e.g., the bioavailability of a metal in soil may be different to an earthworm than to a plant), fundamental (as opposed to site-specific) research requires general indicators of bioavailability. In this research, soil-metal bioavailability will be measured with two in vitro protocols: a physiologically-based extraction test (with an important flow-through modification) to estimate the bioavailability of soil-bound metals in the human gastrointestinal tract and extraction with diethylenetriaminepentaacetic acid (DTPA), a general indicator of ecological bioavailability. The bioavailability of Pb, Zn, Cu, Cd, As, and Ni will be measured as a function of time in metal-spiked soils with a wide range of soil properties. Metal-spiked soils will be used because the initial metal concentration and speciation can be controlled and changes in bioavailability and molecular-level speciation from the initial soluble metal can be followed with time. In addition, beginning with soluble metals will provide insight into the ability of soils themselves to limit metal bioavailability, without regard to any unique site-specific speciation, allowing development of a multivariable linear regression model to predict soil-metal bioavailability on the basis of soil properties. This research will also feature the use of a powerful technique, synchrotron-generated X-ray absorption spectroscopy (XAS), to monitor molecular-level speciation in unaltered soil samples. The research is an innovative response to the statement of need in that it: (1) will develop an a priori means to provide initial estimates of metal bioavailability without regard to site-specific bulk-phase speciation, which is difficult to measure and apply, and which is subject to change over time; (2) will measure the bioavailability of metals in soils relative to soluble metal species which eliminates systematic errors in bioavailability measurements; (3) proposes a dynamic flow-through methodology for measuring bioavailability which more closely replicates physiological conditions; and (4) uses synchrotron-generated XAS to monitor unaltered molecular-level speciation to provide a better fundamental understanding of the relationship between bioavailability and speciation. These results will contribute to DoD's goal of mission readiness by avoiding unnecessary diversion of DoD funds for unwarranted site cleanup.

BENEFIT: These results will provide site managers and risk assessors with tools to make better initial estimates of site risk and environmentally acceptable endpoints (EAE) than using the 100% relative bioavailability default value. Although site-specific data will always need to be considered in making final cleanup decisions, these results can be used to prioritize sites and to justify more definitive site-specific bioavailability studies such as detailed soil speciation investigations and in vivo studies. These results will contribute to DoD's goal of mission readiness by avoiding unnecessary diversion of DoD funds for unwarranted site cleanup.

ACCOMPLISHMENTS: Uncontaminated samples for the spiking experiments were obtained from the USDA-National Resources Conservation Survey. Contaminated samples for validation were obtained from twenty-one DoD facilities based on contaminant concentration, type, and multiple metals at a particular site. Site personnel were contacted to obtain A and upper B horizons from contaminated sites. Soils were targeted for their remediation priority over the next five years involving the removal or containment of the toxic metals As, Cr, Pb, Zn, Cu, Cd, and Ni. These soils will be used in metal treatment experiments involving various loading levels of As, Pb, Cr(III) and Cr(VI). Four Pb-contaminated soil samples previously subjected to in vivo bioavailability testing have been acquired and will be used to test the proposed flow-through modification to the physiologically-based extraction test (PBET). A modified flow-through PBET extraction apparatus has been fabricated to better simulate the continuous flow of soil material through the GI tract. Experiments are underway to compare this extraction technique with the traditional batch PBET method. Experimental work began using four well-characterized soils from the Oak Ridge Reservation. The purpose of these experiments was to develop methods for (a) spiking soils with metals, (b) aging soil samples, (c) testing for mass balances, and (d) validating the approach outlined in the proposal. These methods will be used for testing a wide range of metal-spiked soils. Results have indicated that the presence of soil reduces the bioavailability of Pb and especially As relative to the EPA default value of 100% (even in freshly spiked soils), a major hypothesis of this research. The mass balances also validate the spiking and analysis procedures. Other conclusions relevant to the DoD cleanup mission include: (1) Otherwise labile As, Cr, and Pb are rapidly sequestered in soils dramatically reducing bioavailability, (2) Soil pH and surface charge are key controlling factors in Pb and As bioavailability, and (3) Soil organic matter is a key controlling factor in Cr(III) and Cr(VI) bioavailability. Other contaminated soils were acquired from McClellan Air Force base and three mine waste sites in Utah, Montana, and Alaska. These soils were analyzed with X-ray Absorption Spectroscopy (XAS) to quantify the chemical environment and sorption mechanism of contaminants bound to the solid phase. These results have proven the ability of synchrotron XAS to identify the molecular-level speciation of contaminated soils at DoD facilities. Experiments are now being conducted to measure bioavailability in the approximately thirty contaminated soils collected.

TRANSITION: The results of this research will be transitioned to DoD cleanup activities through both broad-based information transfer and site-specific technology transfer. One of the objectives of this research is to produce a validated, peer-reviewed model to estimate soil metal bioavailability in a wide range of soils based on soil properties. These results will made available to the public through the world-wide web, presentation at scientific meetings, and ultimately publication in refereed archival journals. These results will be extremely beneficial to a risk assessors and site managers as there are currently no methods for estimating bioavailability other than intensive site-specific investigations. The results of this research will also be transferred to specific site cleanup activities through model validation using contaminated soils from McClellan AFB.

PROJECT SUMMARY

PROJECT TITLE & ID: Aerobic and Anaerobic Transformation of cis-DCE and VC: Steps for Reliable Remediation; CU-1167

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. James Tiedje; Michigan State University – East Lansing, MI

FY 2001 FUNDS: $223K

DESCRIPTION: Considerable research has focused on the anaerobic transformation of perchloroethylene (PCE) and trichloroethylene (TCE), which are among the most common chlorinated solvents found in groundwater. However, relatively little is known about the types of microorganisms and specific environmental conditions associated with the dechlorination of cis-1,2-dichloroethene (cis-DCE) and vinyl chloride (VC). Recent research identified four different microbial processes that are involved in the fate of these compounds in groundwater. These processes include anaerobic chlororespiration, anaerobic energy-yielding oxidation, aerobic co-oxidation, and aerobic energy-yielding oxidation. The microbiology of each process will be characterized, and the team of researchers will evaluate each process for its potential applicability for groundwater remediation. Specifically researchers will compare (1) the different dechlorination/degradation processes for their requirements and their rates, (2) subsequently focus on the most viable process(es) or combinations thereof, (3) develop the basic physiological understanding and molecular methods for detection of the most active organisms, and (4) combine the microbial information with site geochemical and activity information to produce criteria for site specific recommendations.

With the current state of knowledge it is not possible to predict which microbial process will be most successful for a particular site. Hence, the first goal is to identify the important bacterial processes that lead to complete detoxification of cis-DCE and VC at high rates. After identifying the relevant processes researchers will focus on the identification, isolation, and physiological and ecological characterization of the important microbial populations involved in these processes. The team will then evaluate how these biological processes can be stimulated, and also what the limitations of the individual processes are. With the knowledge gained from this work researchers will be able to predict how to stimulate the most promising process at a particular site, or whether natural conditions will sustain a sufficient rate.

The following objectives will be addressed during the 3 year period of the proposed research: (1) Identify the processes that result in the rapid degradation of cis-DCE and VC under aerobic and anaerobic conditions. (2) Identify the important groups of organisms involved in cis-DCE and VC degradation/ dechlorination. (3) Determine mechanisms of enhancing the cis-DCE/VC degradation rates of the individual processes. (4) Isolate cis-DCE/VC degrading/dechlorinating organisms in pure culture. (5) Characterize the physiology and phylogeny of the most important cis-DCE/VC degrading/dechlorinating organisms. (6) Investigate how site-specific characteristics determine which of the above identified processes is the most promising bioremediation strategy. (7) Develop a protocol to evaluate site-specific characteristics in order to facilitate decisions on which process is most promising for a particular site.

BENEFIT: Laboratory research in this project will provide insight into which factors may control anaerobic and aerobic transformation of cis-DCE and VC. The results of microcosm studies identifying appropriate environmental conditions for cis-DCE and VC transformation will be compared to field geochemcial and VOC data from site A (Wisconsin) and the Bachman Road site. This comparison will aid in determining whether an observed lack of transformation is due to inappropriate geochemical conditions or the absence of relevant microbial populations. Ultimately, this research will identify which geochemical and microbial factors should be evaluated in determining the fate of chlorinated ethenes at a site. Natural attenuation and engineered bioremediation are often the most cost-effective corrective actions for addressing groundwater contaminated with cis-DCE and VC. By conducting additional field geochemical measurements and laboratory studies to characterize biodegradation at a site, these cost-effective remedial options can be reliably identified. The additional cost of conducting these studies, typically $30,000-40,000, is recovered by avoiding installation or long-term operation of a "pump and treat" system. In addition, information from these studies can be used in designing in situ biostimulation processes for cis-DCE and VC degradation.

ACCOMPLISHMENTS: Aquifer materials have been collected from the Savannah River site, SC and the Bachman Road site, NJ. Samples will soon be collected from the Hydrite site, WI. Careful evaluation of field data obtained from the Hydrite site suggest that processes 2 (reductive dechlorination), 3 (anaerobic oxidation), and 5 (aerobic, energy-yielding oxidation) occur in the different redox zones of this aquifer. Microcosms including appropriate controls to evaluate the potential of the different microbial processes (processes 2 to 5) to degrade cis-DCE and VC were established with the aquifer materials collected from the Savannah River site and the Bachman Road site. Three different electron donors, hydrogen, acetate, and lactate, are being tested to stimulate the reductive dechlorination process and to enrich cis-DCE- and VC-respiring populations. Anaerobic oxidation of the target compounds is being evaluated under denitrifying, iron-reducing, and manganese-reducing conditions. Microcosms to enrich organisms that grow with cis-DCE or VC as the sole source of carbon and energy were established with magnesium peroxide as an oxygen-releasing compound. Preliminary data show that aerobic VC degradation occurred in microcosms established with aquifer material from the Bachman Road site and in cultures established with groundwater obtained from a waste site in Stillwater, OK. A defined mixed culture growing with TCE as the terminal electron acceptor was obtained in previous work. This mixed culture consists of no more than three distinct populations and grows in a defined medium. *A Dehalococcoides* species was identified as the TCE-dechlorination population, and the other two populations were isolated. The only pure culture of *a Dehalococcoides* species currently available requires unidentified growth factors and does not grow in defined media. The defined tri-culture is an ideal system to explore the growth requirements of the TCE-dechlorinating *Dehalococcoides* species, and experiments to characterize these growth factors were initiated.

TRANSITION: This project will be developing a site characterization protocol for use in feasibility studies at sites contaminated by chlorinated solvents. This protocol would complement existing documents, such as the Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water (EPA/600/R-98/128). A flowchart will be developed to aid the practitioner in identifying which chlorinated solvent transformation process may be relevant at a site. Rate constants of cis-DCE and VC transformation in microcosm studies will also be included to aid in modeling studies.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of the Aerobic Oxidation of cis-DCE and VC in Support of Bioremediation of Chloroethene-Contaminated Sites; CU-1168

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. James Gossett; Cornell University – Ithaca, NY

FY 2001 FUNDS: $275K

DESCRIPTION: The lesser chlorinated ethenes , cis-1,2-dichloroethene (cDCE) and vinyl chloride (VC), tend to accumulate at chloroethene-contaminated sites under anaerobic conditions, limiting the application of natural attenuation and enhanced reductive anaerobic in-situ treatment technologies. Aerobic degradation of lesser-chlorinated ethenes has been demonstrated; however, present understanding of the transformation potentials of cDCE and VC is limited, thus limiting the reliability of, and confidence in, natural and enhanced biological alternatives for site remediation.

This project will try to determine the distribution and metabolic capabilities of microorganisms able to mineralize cDCE and/or VC in aerobic subsurface environments. Five candidate sites will be studied, and two complementary approaches will be used to locate organisms capable of growth-coupled, aerobic oxidation of cDCE and/or VC at contaminated sites: microcosm enrichments and direct isolations from site material. Once located, the organisms will be isolated and characterized. The relationships that may exist between chloroethene degraders and ethene degraders from each site will be evaluated to determine whether the chloroethene degraders were derived from the indigenous ethene degraders. Once the relationship between ethene degraders and chloroethene degraders is clear, spatial distribution of aerobic chloroethene degradation and the distribution of chloroethene-oxidizing bacteria in the field will be assessed. The results will delineate the roles of cometabolism vs. growth-coupled degradation in the natural attenuation of lesser-chlorinated ethenes. A better understanding of these growth-coupled, aerobic oxidative pathways should expand the number of sites judged suitable for bioremediation alternatives (natural and enhanced), with potential savings to DoD in the millions of dollars.

BENEFIT: The results will delineate the roles of cometabolism vs. growth-coupled degradation in the natural attenuation of lesser-chlorinated ethenes. The findings are expected to shed much-needed light on the aerobic transformations of lesser-chlorinated ethenes compounds currently limiting the efficacy of natural attenuation and enhanced bioremediation of candidate sites. Results are thus expected to lead to improved site assessment (sites can be screened for existing and potential aerobic oxidative degradation activities); improved remedial-action decision-making (the effects of oxidative mechanisms can be better taken into account in modeling either natural attenuation or the effects of enhancement alternatives); and more reliable bioremediation technologies (enhancement strategies can be developed to take advantage of the aerobic transformation mechanisms). A better understanding of these growth-coupled, aerobic oxidative pathways should expand the number of sites judged suitable for bioremediation alternatives (natural and enhanced), with potential savings to DoD in the millions of dollars.

ACCOMPLISHMENTS: Material has been obtained from several promising sites where cDCE and/or VC oxidizers may exist. Microcosms and/or direct enrichments were prepared from each, and enrichment attempts are underway. Different amounts of VC were added to subsamples from one active enrichment to test the tolerance of the enrichment to higher VC concentrations. These secondary enrichments have shown good degradation at all VC concentrations tested. By plating the initial enrichment culture onto 1/10 TSA plates, three colony types were observed, one of which is by far the most predominant. This most abundant strain is a Gram negative rod. Attempts to subculture in minimal medium with various carbon sources have begun. The nutritional requirements of this strain have not yet been investigated, although if it turns out to be capable of degrading VC in pure culture, it will become an immediate focus of experiments. cDCE oxidation is yet to be observed in any of these studies, but VC oxidation is proving to be relatively common. Successful cultures have been transferred several times in mineral medium. The two pure cultures identified have been sent for ribosomal DNA sequencing, and results show that they are both *Mycobacterium* strains although different from one another.

TRANSITION: Transition would occur by the following: (1) Incorporation of the aerobic, oxidative pathways into comprehensive fate- and-transport models, providing site managers with enhanced tools for decision-making; (2) incorporation of the findings into both Air Force and EPA natural- attenuation protocols for chlorinated ethenes; and (3) incorporation of the results into the ESTCP protocol for assessment of suitability for Reductive Anaerobic Biological In-Situ Treatment Technology (RABITT).

PROJECT SUMMARY

PROJECT TITLE & ID: Factors Affecting cis-DCE and VC Biological Transformation under Anaerobic Conditions; CU-1169

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Alfred Spormann; Stanford University – Stanford, CA

FY 2001 FUNDS: $275K

DESCRIPTION: The objective of this project is to establish a better understanding of aerobic and anaerobic transformation of cis-dichloroethene (cis-DCE) and vinyl chloride (VC). The chlorinated solvents, trichloroethene (TCE), tetrachloroethene (PCE), and carbon tetrachloride (CT) have been widely used by industry, the Department of Defense (DoD), and the Department of Energy (DOE) as solvents for cleaning. Through leakage and poor disposal practices, these solvents have become the most frequent groundwater contaminants throughout the country, causing one of the most difficult and costly contamination problems for remediation. Significant groundwater contamination with these solvents exist at DOE facilities. Most remediation approaches involve the extraction of contaminated groundwater and its cleanup at the surface through expensive physical and/or chemical methods. However, anaerobic biological processes have resulted in the natural destruction (intrinsic bioremediation) of the chlorinated solvents in some cases. cis-DCE and VC are intermediates in the biological reductive dehalogenation of PCE and TCE. Molecular hydrogen appears to be a key electron donor for these reductive processes. However, the transformation of cis-DCE to VC, and of VC to ethene is very slow. A major question raised in such biodegradation is why the process does not go to completion to ethene. How can hydrogen most effectively be funneled towards reductive dehalogenation of cDCE and VC? How can one determine at a given site the reason for lack of complete biodegradation? This proposal is for laboratory studies to better understand these questions and to develop procedures that can be used in the field for their evaluation.

The study will be conducted in five separate phases:

- ***Microorganisms, enzymes, and mechanisms involved in anaerobic reduction of cDCE and VC, and development of molecular probes.*** In this sub-project, researchers will isolate and purify the enzyme(s) catalyzing cDCE and VC reduction. They will conduct molecular analyses on the proteins and clone the encoding genes and will construct a molecular probe to monitor the genes and the process of cDCE and VC reduction, and test the probe in laboratory studies and field samples.

- ***Kinetics of cDCE and VC reductive dehalogenation.*** Project team members will experimentally evaluate a dual substrate model for cDCE and VC reduction with H_2 as electron donor. Team members will specially consider low substrate concentrations which are relevant for in situ transformations. This model will be tested with different dehalogenating cultures.

- ***Evaluation of potential chemical factors that may affect these processes.*** Researchers will test whether the end products of cDCE and VC reduction, ethene and ethane, as well as other chlorinated ethenes and alkanes that are frequently present at contaminated sites, will inhibit cDCE and VC reduction and determine the extent of inhibition.

- ***Development of a field procedure for estimating the presence of and the rate of release of electron donors for reductive dehalogenation.*** Researchers will develop a procedure to measure the rate of hydrogen production in a given aquifer sample and the fraction that is available for reductive dehalogenation. Once validated under careful laboratory conditions, it will be used on aquifer samples to test its usefulness for determining hydrogen availability at given sites for dehalogenation of cDCE and VC.

- ***Isolation of anaerobic cDCE and VC oxidizing microorganisms and determination of the kinetics of anaerobic cDCE and VC oxidation.*** Team members will set up enrichment cultures for anaerobic cDCE and VC-oxidizing microorganisms that use nitrate, Fe^{+3} or CO_2 as terminal electron acceptors, respectively. Researchers will characterize the microbial community using molecular methods and attempt the isolation of pure anaerobic, cDCE and VC oxidizing strains. Relevant kinetic parameters of the mixed cultures and the pure cultures will be determined as done previously for cDCE and VC reducing cultures.

BENEFIT: The expected benefits of this research are the following: (1) New basic information on the mechanism of biological reductive dehalogenation of cDCE and VC. (2) Molecular probes for reductive VC dehalogenation. (3) Test of mathematical model for growth limitation at low substrate concentrations. (4) Data on inhibition of cDCE and VC reductive dehalogenation by other co-contaminants. (5) Field procedure to determine availability of hydrogen for reductive dehalogenation. (6) New basic information on microbiology of anaerobic cDCE and VC oxidation. (7) Evaluate the molecular probes that were developed with material from field sites, and correlate probe signals with reductive cDCE and VC dehalogenation. (8) Test anaerobic cDCE and VC oxidation as engineering alternative for reductive cDCE and VC dehalogenation. (9) Evaluate potential for reductive cDCE and VC dehalogenation of related enzymes. (10) Simplify field procedure to measure electron donor release for simple use at field sites.

ACCOMPLISHMENTS: An experimental system to determine cDCE and VC dehalogenation rates at low hydrogen concentrations was successfully established. Experimental data were fit by non-linear least squares analyses to estimate the affinity constant for hydrogen (K_H). The resulting K_H value was within the bounds of that estimated by Ballapragada et al. providing confidence in the results of this preliminary study. Growth of anaerobic VC dehalogenating culture was optimized. Preliminary results have shown that substituting hydrogen with pyruvate as the electron donor decreased the doubling time by 20%. A further decrease was observed when incubating the culture at 30°C but not at 37°C. To inhibit homoacetogenic bacteria in the culture, the bicarbonate buffer was substituted with phosphate, MOPS or HEPES (15 mM each). Dehalogenation rate was unchanged after 6 transfers in HEPES. Major groups of microorganisms in the VC dehalogenating culture were identified. Preliminary phylogenetic analysis of the VC dehalogenating culture have shown that the VC dehalogenating culture contains at least 4-5 different morphotypes: (1) long, thin rods; (2) short, thick rods; (3) thin spirilli; (4) very small rods; and (5) very small cocci. Morphotypes 1-3 are dominant (~80% of total numbers). Genes encoding the 16S rRNA were obtained from the culture by PCR amplification and partially sequenced. The strongest similarity of dominant members include Sporomusa sphaeroides, Clostridium propionicum, and uncultured bacterium SJA-112. N-terminal sequences of reductive VC dehalogenase were determined (a) from membrane-associated peptides that are present only in VC-grown cultures, and (b) from peptides of the highly enriched VC reductase. A 107 kDa and a 62 kDa protein was present in both preparations. From these proteins, internal amino acid sequences were determined, and in conjunction with the respective N-terminal sequence, the gene(s) encoding the reductive VC will be isolated and sequenced.

TRANSITION: The research that has been conducted over the past several years on reductive dehalogenation has been used by DuPont in the application of reductive dehalogenation for enhanced bioremediation of PCE and TCE at their own sites, and in conjunction with the Remediation Technology Development Forum (RTDF) studies with EPA, DOE, and DoD. The researchers have helped advise the development of enrichment cultures for bioaugmentation and on the requirements for carrying out this process. Through these cooperative studies, the results of this research will be quickly disseminated to the RTDF consortium members and others.

PROJECT SUMMARY

PROJECT TITLE & ID: Assessment of the Potential for Microgravimetry in Remote Discrimination and Identification of Buried UXO; CU-1170 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Dwain Butler; U.S. Army Corps of Engineers Engineer Research and Development Center, Environmental Laboratory – Vicksburg, MS

FY 2000 COMPLETED PROJECT

DESCRIPTION: This project investigated the potential role of microgravimetry for buried unexploded ordnance (UXO) discrimination and identification. Localized anomalies detected by gravity surveys are related to density contrasts and hence to mass excess or deficiency of a localized feature relative to the surrounding material. Microgravimetry involves high-resolution, high-accuracy measurements of very small anomalies in the gravitational field (of the order 10-9 of the nominal earth's gravity field), such as would be caused by presence of buried UXO. Detecting the gravitational anomaly caused by a UXO or non-UXO item will allow determination of the mass of the item. Coupled with ferrous volume estimates from magnetic surveys, UXO/non-UXO discrimination is possible.

Microgravimetry has potential applicability to localized area interrogation for UXO discrimination and identification. Microgravimetry is the only geophysical method that can give direct estimates of the actual mass of the UXO. Microgravimetry requires very careful, high accuracy measurements of the local variations of the earth's gravity field. A primary limitation to microgravity surveys in the past has been the time required to survey site elevations, make gravity measurements, and then process the data. Generally, once the microgravity data is acquired, considerable time is required to process the data and make interpretations. With the very recent emergence of near-real time microgravity, which uses digital gravimeters, dynamic "on the fly" surveying for positioning and elevation, and in-field processing, microgravimetry is now potentially applicable to problems not considered practical in the past

The study concentrated on compiling mass and volume values for ordnance items, developing a microgravity modeling capability for a prolate spheroid geometry, generation of model gravity anomaly signatures, assessing detectability (anomaly magnitude versus depth for selected ordnance items), determining spatial sampling (measurement spacing) requirements, and assessing the potential for gravity inversion to give model parameters. The prolate spheroid gravity modeling program required developing a complete analytical solution for the gravity anomaly on the surface above the model in a layered half-space. The solution would have been valid for any orientation of the prolate spheroid model. A limited microgravity field investigation was conducted. Microgravity measurements were acquired above several buried ordnance objects, e.g., a 500-lb bomb and a 155-mm projectile. Additionally, data may be acquired above an buried, empty 55-gallon drum. There were two primary technical risks for this project:

- The realm of applicability of microgravity is too limited in terms of object size and depth of burial to play a significant role is buried UXO discrimination;
- The microgravity data acquisition is too costly and/or time-consuming to be a viable UXO discrimination tool.

BENEFIT: The immediate benefit would have been enhanced capability for discrimination of UXO from other buried objects based on the microgravity anomaly. The approach had the greatest potential for the larger buried UXO, e.g., 155-mm projectiles and larger, where the pay-off for discrimination prior to excavation is highest, due to cost of excavation and safety considerations. The long-term payoff of the research was the potential for UXO identification by joint inversion (interpretation) of gravity, magnetic and/or electromagnetic data sets.

ACCOMPLISHMENTS: A prototype FORTRAN algorithm was developed for forward solution. The analytical gravity signature calculation procedure for prolate spheroid UXO model with graphical output was completed. Gravity signatures (2-D) were calculated for fourteen model UXO using average length, diameter, mass, and bulk density for the UXO class and a typical soil density. Microgravity has been deemed not applicable for remote discrimination and identification of buried UXO.

TRANSITION: If the research had been proven successful, the results and recommendations from this exploratory development investigation would have provided the basis for possible execution of a larger research effort.

PROJECT SUMMARY

PROJECT TITLE & ID: Multiple Frequency Induction Measurements for Enhanced Buried UXO Discrimination; CU-1171 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Ernie Cespedes; U.S. Army Corps of Engineers Engineer Research and Development Center, Environmental Laboratory – Vicksburg, MS

FY 2000 COMPLETED PROJECT

DESCRIPTION: This project consisted of developing and evaluating a novel sensing/processing system to measure the complex electromagnetic induction properties of buried unexploded ordnance (UXO) at multiple audio frequencies (30 to 30,000 Hz). The objective was to develop a low-cost, multiple frequency electromagnetic induction (EMI) device for UXO discrimination which overcomes the limitations associated with current frequency domain electromagnetic (FDEM) approaches. The approach was to develop a prototype coil and data analysis EMI system that can simultaneously transmit multiple frequencies and rapidly measure the complex properties of buried metallic object. This approach was based on a single coil (monostatic) design which overcomes: (1) poor spatial resolution associated with current bistatic sensors, (2) poor discrimination capability of single-frequency systems, and (3) limited depth of investigation associated with bucking coil systems.

This proposed approach relied on a single coil that is energized by a composite signal that contains multiple audio frequencies of equal amplitudes and known phase. Rather than depending on physical separation of transmitter and receiver coils (bistatic methods) or using additional coils for bucking the primary field, the researchers used the single coil for both excitation and measurement and will rely on signal processing to separate the relatively weak signals generated by buried conductive targets from the high-energy excitation signals. The success of this effort depended to a large extent on optimizing an antenna (coil) design so that materials in proximity to the antenna affect the induction of the antenna. The design maximized the dynamic range of induction response of the antenna to varied materials. The approach to the development of this antenna was a standard engineering task and consisted of calculations and laboratory measurements to select five antenna designs that will theoretically be inherently sensitive to external materials. These designs will then be experimentally characterized using an integrated digital system. The digital control, signal generation, data acquisition and analysis system will consist of a small laptop or palm top computer, two sound cards and an audio amplifier. A two- channel excitation signal was generated and stored as a wavetable file for each antenna. This signal included multiple audio frequency components, and had the characteristic that the power spectral density is flat, that is, an equal amount of power was distributed into each frequency component. The two channels of the signal was amplified using low-cost Metal-Oxide Semiconductor Field-Effect Transistor (MOSFET) components and one channel was fed into the antenna, and the other fed into a dummy load as a reference. This reference allowed for the correction of drift that is common in current EMI systems. Both output signals were then recorded using a second sound card. The inductive reactance response as a function of frequency for the antenna in free space was related to the response of the dummy load. This was used to develop a transformation so that the free space spectral response of the antenna can be calculated from the signal observed in the dummy load. Since the actual signal that was observed in the antenna is a combination of the free space response and the coupling of the radiation to the environment, the signal that is induced by the coupling of the field with the environment can be calculated. Once this signal is extracted it can then be used to calculate inductance, and ultimately the complex (inphase and quadrature) response of the environment.

BENEFIT: The immediate benefit of the SERDP investment will be a prototype EMI sensor that will provide performance improvements over current UXO detection/discrimination technologies. If successful, such a system could produce significant cost savings in UXO remediation projects where currently over 75 percent of the costs are due to excavating non-hazardous objects (false alarms). It is estimated that emerging multifrequency/multichannel sensors, such as the system envisioned in this effort, will reduce the current false alarm rates by as much as 90% while maintaining high (over 90%) probability of detection.

ACCOMPLISHMENTS: A variety of transmitter/receiver coils for laboratory evaluation/optimization were designed and fabricated. Initial analysis provided good quality frequency domain data from the measurements and indicated that a detector system that uses interchangeable multiple coils based on expected target size/depth considerations may be desirable. Signal generation, data acquisition, and analysis hardware/software systems were developed. Alternate approaches to improve optimization were developed and tested. Methods for improving the accuracy of phase measurements, particularly at the higher frequencies where both frequency domain (PSD) and time domain (zero crossings)methods suffered from significant errors (compared to theoretical predictions), were developed. Errors in the phase calculations were caused by very small uncertainties in the synchronization between the signal generator and the data recorder. New synchronization techniques were implemented, and the errors were reduced to acceptable levels. Laboratory evaluations were completed and shortcomings were identified. Data collection was completed using optimized prototype design and complementary data with commercially available multifrequency EM system to compare capabilities was collected. Difficulties were experienced extracting accurate phase information from the two receiver coils, and problems related to the presence of random voltage spikes at the transmitter and receiver coils were encountered. Tests using precision-wound coils were completed. Signal to noise ratio (SNR) performance of various transmitter-receiver coil configurations with a range of canonical and UXO targets was measured. Experimental data was compared with model results and problems were noted in the high frequency portion of the spectra due to continuing difficulties in accurately measuring phase information. A high resolution digital phase tracking amplifier was acquired to determine if phase measurement capability could be improved.

TRANSITION: If the prototype system developed under the proposed effort had met performance expectations (i.e., enhanced UXO discrimination at greater burial depths than current FDEM systems), researchers would have transitioned this technology to full scale field demonstration and follow-on transition to Corps of Engineers and commercial UXO users. Based on previous and ongoing collaborations with Geophex Ltd., lead researchers will pursue a CRADA for the commercialization and fielding of the enhanced technologies.

PROJECT SUMMARY

PROJECT TITLE & ID: Novel Acoustic Technique for UXO Discrimination; CU-1172 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Thomas Bell; AETC, Inc. – Arlington, VA

FY 2000 COMPLETED PROJECT

DESCRIPTION: The objective was to demonstrate that a simple seismic device consisting of an impact source and a few receiver elements can be used to discriminate between buried unexploded ordnance (UXO) and clutter. Researchers measured Rayleigh wave backscatter from suspected targets using standard Spectral Analysis of Surface Wave (SASW) technology. UXO/clutter discrimination was based on backscatter variations with aspect angle. The basic SASW test configuration includes an impact source and a pair of receivers. The backscatter is manifested in interference effects in the frequency dependent phase shift between the signal at the two receivers. The team demonstrated that, when measured over a range aspect angles relative to a suspected target, the frequency dependent phase shifts among the signals measured at the receivers contain a unique "signature" of the target that can be exploited to discriminate between buried UXO and clutter.

The standard SASW test included an impact source that generates a spectrum of elastic waves and a pair of receivers. Researchers are interested in interference effects, due to waves scattered by the target, in the frequency dependent phase shift between the signals at the two receivers. The phase shift was calculated directly from the cross-spectrum of the signals at the two receivers. Normally (i.e., when there is nothing buried in the ground) this phase shift is used to calculate the Rayleigh wave phase speed as a function of frequency. (Since the scattering function is complex - it includes both the amplitude and the phase shift of the reflected wave relative to the incident wave - the phase shifts need to be between two pairs of receivers in order to estimate it, which means adding a third receiver to the basic SASW configuration.) The target signature will also depend on target size and depth and on the source-receiver geometry in relationship to the target (x,y) location. However, these are known and/or controlled variables. Target location, size and depth can usually be accurately estimated from the cueing sensor data, and the sensor geometry can be adjusted as appropriate.

UXO should have fairly simple characteristic scattering functions. The basic questions are (1) whether they are sufficiently different from the scattering functions of most clutter items to be useful for discrimination, and (2) whether they can be adequately estimated from data collected in the field. The critical issues that will be addressed here are how well the scattering data can be represented using a simple physics-based response model, and whether or not differences among the signatures of different types of targets are large enough compared to the variability due to reasonable uncertainties in target size, depth and location to be useful for classification and discrimination.

BENEFIT: The expected outcome of this exploratory development effort is a verification that a simple seismic device consisting of an impact source and a few receiver elements can provide data useful in discriminating between buried UXO and clutter. The basic technology is simple, rugged, and highly portable. When fully developed, researchers envision a system that can be operated by a single technician to perform cued discrimination in the field. This capability can significantly reduce the cost of remediating UXO contaminated land. At present, on a typical job about 75% of remediation costs result from digging non-ordnance targets.

ACCOMPLISHMENTS: Initial data measurements were compromised by high levels of frame vibration. A new frame to counteract these vibrations was obtained. Data has been collected for all four targets at various aspect angles. Signal dependence on target and orientation has been demonstrated.

TRANSITION: The expected outcome of this exploratory development effort is a verification that a simple seismic device consisting of an impact source and a few receiver elements can provide data useful in discriminating between buried UXO and clutter. The critical issues that will be addressed here are (1) how well the scattering data can be represented using a simple physics-based response model, and (2) whether or not differences among the signatures of different types of targets are large enough compared to the variability due to reasonable uncertainties in target size, depth and location to be useful for classification and discrimination. If this proof-of-concept is successful, additional research will be needed to optimize measurement configurations, develop robust processing of algorithms and establish performance bounds for UXO/clutter discrimination.

PROJECT SUMMARY

PROJECT TITLE & ID: SAR/GPR Matched Filter Processing for UXO Discrimination; CU-1173 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. George Moussally; Mirage Systems – Sunnyvale, CA

FY 2000 COMPLETED PROJECT

DESCRIPTION: The goal of this project was to demonstrate a data processing technique using measured ground penetrating radar (GPR) data that will significantly reduce the number of false positives when characterizing unexploded ordnance (UXO) contaminated sites.

This project developed the use of an existing standoff GPR system operating in a synthetic aperture radar (SAR) mode to collect data on buried UXO targets. Researchers then processed the collected GPR data into SAR imagery by incorporating radar scattering models of the general set of UXO targets of interest directly into the imaging process. Researchers discriminated UXO target types by comparing the target-specific SAR imagery with conventional SAR imagery (i.e., imagery that makes no assumptions about specific target types), and then quantified the projected benefit of this processing technique to reduce the number of false alarms when characterizing UXO sites.

BENEFIT: Development of an effective matched filtering processing technique for use with a SAR/GPR offers the potential for significant improvement of UXO discrimination with this type of sensor. When coupled with the high surveying productivity of a standoff GPR, the technique could produce very useable and reliable site characterization reports featuring good detection and low false positives in a cost effective manner. Cost benefits would be derived from two key features: (1) the reduction in false positives leading to a reduction of fruitless digs, and (2) the high rates of survey productivity (up to 10 acres /hr for ground-based systems and up to 200 acres per hr for airborne systems) leading to reduced survey costs.

ACCOMPLISHMENTS: The UXO target set to be used in measurements was defined and obtained. Target set computer models were developed to predict target scattering characteristics of these targets when they are buried. The NEC4 electromagnetic modeling program has been installed and the installation validated by using examples included with the code. The NEC4 code was modified to supply complex scattering measurements in the horizontal and vertical planes for all frequencies and for all incidence angles for the mono-static GPR system. A number of wire frame target models were generated for input to NEC4. Models were generated to provide accurate scattering predictions while maintaining reasonable processing requirements. Target matched filters were calculated. Field measurements were completed through data collection at Yuma Proving Grounds (YPG). Simulated SAR radar data processing has been completed. YPG SAR data processing is in progress. Preliminary processing of the data indicates that the matched filter processing technique can yield significant processing gains that can favorably impact false alarm reduction. Matched filter processing, theoretically, has the potential to increase target signal processing for UXO targets by 15 -20 dB. Actual gains achieved to date are in the range of 0 - 6 dB. It is suspected that antenna calibration may be a limiting factor. Calibration sensitivity analysis is currently being performed with plans to iterate antenna calibration against reference surface targets. Processing gains of ~3 dB or more would have a significant impact on false alarm rates. It is expected that gains between 6 - 10 dB may be achievable. The complete false alarm analysis is yet to be conducted.

TRANSITION: Development of an effective matched filtering processing technique for use with a SAR GPR offers the potential for significant improvement of UXO discrimination with this type of sensor. When coupled with the high surveying productivity of a standoff GPR, the technique could produce very useable and reliable site characterization reports featuring good detection and low false positives in a cost effective manner. This discrimination capability, with acceptable detection and false alarm statistics, is also critical for use of SAR GPRs in tactical and humanitarian dernining applications. Previous analyses of test site surveys performed under Army-sponsored UXO detection technologies evaluations revealed serious shortcomings, such as a large number of false positives due to a lack of discrimination capability from background/clutter effects and the interfering signals. The proposed project directly attacks this problem and offers promise of providing an practically implementable solution.

PROJECT SUMMARY

PROJECT TITLE & ID: Detection and Classification of Buried Metallic Objects; CU-1174 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. H. Frank Morrison; Lawrence Berkeley National Laboratory – Berkeley, CA

FY 2000 COMPLETED PROJECT

DESCRIPTION: Because detection and identification of metallic minerals is an important part of geophysical exploration, researchers have developed considerable expertise in the use of numerical modeling algorithms to simulate the response of electrically conducting objects to various types of detectors. This project modified existing computer programs to study the behavior of a variety of landmine and unexploded ordinance (UXO) targets buried in different positions and ground conditions. This gave quantitative criteria for evaluating the effectiveness of various land-based metal detection systems. The results will enable the researchers to propose the design of a new system which, in addition to locating targets, will be optimized to determine their size, shape and orientation and the depth at which they are buried. This system will be sensitive enough to suggest physical characteristics of buried objects, including their electrical conductivity, magnetic permeability, and the presence of electrically insulating (plastic) shells surrounding them. This information will enable a user to accurately discriminate between landmines, UXO and spurious metallic debris.

This project proposed to use numerical model simulators, which have been developed by geophysicists in the mineral exploration community, to design and prototype an active electromagnetic system for detecting and characterizing the metal content of mines and UXO against a background of geologic materials and other metal objects. An optimized metal detector was developed with the capacity to determine the following physical properties of a buried metal object: (1) depth; (2) size, shape and orientation; (3) electrical conductivity; (4) magnetic permeability; and, (5) state of contact with the ground (insulated or not).

The design was adapted to a portable, hand-held, battery powered system with a user friendly display of the target response, and also to a larger mounted system which can be used to search the broad area in front of a vehicle. The general design included a variable-frequency transmitter which produced a known magnetic field. This primary field induced electric currents in the target which then produced magnetic fields which will be measured by the receiver. The results of numerical simulation of target responses were used to tune the system, determine the optimum frequency range and transmitter-receiver configuration to produce the largest and most diagnostic response of the target using the smallest expenditure of power in the transmitter.

BENEFIT: The mineral exploration community has used electromagnetic (EM) methods to detect the electrically conductive metallic minerals which are the source of much of the world's supply of copper, lead, zinc and gold. Because of the complexity and economic importance of mineral deposits, a vast amount of research has been devoted developing methods of finding and characterizing them. Much of the research of the geophysical community has been to develop a quantitative understanding of the characteristic behavior of many different kinds of metallic objects located in a variety of positions and backgrounds. A new generation of electromagnetic sensing systems is now possible that could screen large areas or provide high-resolution classification of particular targets. Drawing on extensive experience with large scale mineral exploration EM systems, numerical simulators for quantitative modeling, and recent work in model based classification algorithms the research team proposes a computer based design of an optimum system specifically to meet the needs UXO Detection and Discrimination."

ACCOMPLISHMENTS: A numerical simulator for determining the EM response of a simple thin sheet target in a conductive ground was implemented. The thin sheet response illustrates an optimization methodology that can be implemented for any target. A simple criterion for evaluating any transmitter-receiver (TR) configuration by maximizing the ratio of the target response to the background half-space response, the Anomaly Index, was developed. A rationale for evaluating the signal to noise ratio for an arbitrary TR system considering ambient EM noise, system noise, array separation/orientation noise and geologic noise was developed. Overall guidelines for the design of an optimum EM system were established.

TRANSITION: This proposed system may replace the object-specific metal locators now in use worldwide. Project researchers will begin immediately identifying suitable partners for transitioning the design to an implementation and fabrication group. To this end the researchers plan to sponsor a small workshop of those individuals currently involved in developing EM systems for UXO detection.

PROJECT SUMMARY

PROJECT TITLE & ID: Fe(O)-Based-Bioremediation of RDX-Contaminated Aquifers; CU-1175 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Pedro Alvarez, P.E., DEE; The University of Iowa – Iowa City, IA

FY 2000 COMPLETED PROJECT

DESCRIPTION: Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) is the British code name for Royal Demolition Explosive. RDX is toxic to humans and a variety of organisms, and is classified as a Class C (possible human) carcinogen by the U.S. EPA. Toxicity studies have led the Surgeon General to recommend a 24-h maximum RDX concentration of 0.3 mg/l to protect aquatic life. The Office of Drinking Water has set a limit for lifetime exposure to RDX at 0.1 mg/l. Because of its recalcitrance to microbial degradation, low tendency to volatilize and high mobility in aquifers, clean-up of RDX contaminated sites is a challenging problem. Current practices to remove RDX from contaminated soil include incineration, composting, alkaline hydrolysis/oxidation, and aqueous thermal decomposition. However, these ex situ approaches are not cost-effective to treat large volumes of contaminated groundwater. In addition, complete destruction of RDX is not always achieved, giving rise to the possibility that products of equal or greater toxicity accumulate. This project is planning to develop a new and efficient method to remediate RDX-contaminated aquifers. This method is based on combining a novel chemical process [reductive treatment with Fe(O)] with a promising bioremediation approach (in situ reactive zones). This integrated Fe(O)-microbial system should improve the capability and reduce the cost of RDX remediation efforts.

The specific goal of this one-year project was to delineate the applicability and limitations of biologically-active Fe(O) barriers to manage RDX plumes. To achieve this goal, the researchers needed to answer numerous questions related to the feasibility of Fe(O)-based bioremediation, e.g., what is the fate of RDX in combined microbial-Fe(O) treatment systems? Is the combination of Fe(O) with anaerobic bacteria synergistic in terms of contaminant removal rates? Is there a need to add acclimated microorganisms, or will an indigenous hydrogenotrophic consortium eventually develop around Fe(O) barriers to fill a metabolic niche associated with cathodic depolarization and RDX biodegradation? How long does it take for such a natural consortium to develop? Other questions should be addressed to obtain basic criteria for process design and operation, e.g., what rate law does RDX removal follow? What should be the Fe(O) surface area concentration to optimize desirable biogeochemical interactions? How long does Fe(O) or the added bacteria remain active? How do pH, temperature, and redox conditions affect RDX removal kinetics and end product distribution? Can thinner barriers be used as a pre-treatment step to enhance RDX mineralization by (downgradient) indigenous microorganisms? How do microorganisms affect the hydraulic performance and long-term reactivity of the barrier? The project completed these specific tasks to answer the questions from above. (1) Compare the fate and degradation kinetics of 14C-labeled RDX in soil microcosms amended with Fe(O), anaerobic mixed cultures, both, or none. (2) Identify soluble degradation intermediates and end products for each treatment. (3) Determine if indigenous aquifer microorganisms colonize the Fe(O) surface, and how microbial growth and (cathodic) H_2 gas consumption affect the permeability of flow-through aquifer columns. (4) Determine how hydraulic loading of the columns affects RDX removal efficiency.

BENEFIT: An integrated microbial-Fe(O) treatment systems may offer significant advantages over approaches where either process is used alone. Specifically, bioaugmentation of Fe(O) barriers with pre-acclimated anaerobic bacteria will enhance the treatment of RDX plumes by increasing both the rate and extent of transformation and by yielding a more favorable product distribution when compared to treatment with Fe(O) alone or anaerobic bacteria alone. This synergism is hypothesized to be due to several factors. Fe(O) corrosion rapidly induces anoxic conditions that favor RDX biotransformations. The production of cathodic (water-derived) hydrogen by Fe(O) corrosion would increase the availability of an excellent primary substrate to support microbial reduction of RDX and the further degradation of some dead-end products that accumulate during abiotic reduction by Fe(O). Hydrogenotrophs could also remove the passivating cathodic H_2 layer from the Fe(O) surface, which could enhance the reactivity of Fe(O) (i.e., cathodic depolarization). Microbial consumption of H_2 gas bubbles may also enhance the permeability of the barrier to offset any decrease in permeability resulting from microbial growth. Alternatively, the reduction of RDX by Fe(O) enhances its subsequent biodegradability. Thus, a sequential scheme where a pre-treatment Fe(O) barrier is followed by down-gradient bioremediation of any products that break through might also be a viable alternative to clean up RDX contaminated aquifers.

ACCOMPLISHMENTS: Results of batch experiments have shown that iron degrades RDX faster than it degrades other pollutants commonly treated with iron barriers. Combining anaerobic bacteria with iron is synergistic in terms of the rates and extent of mineralization, and this synergism is due in part to H_2 production during iron corrosion which stimulates reductive biotransformations. Experiments were also conducted to determine if RDX can inhibit microbial activity, and if so, if contacting RDX with Fe(O) would enhance its subsequent biodegradability under either aerobic or anaerobic conditions. Results showed that exposing RDX to Fe(O) increased the feasibility of anaerobic post-treatment. Experiments were also conducted to compare the fate and rate and extent of RDX mineralization in different treatments. Apparently, RDX can be polymerized with some surface material and become less bioavailable. Whether this pathway leads to an acceptable treatment endpoint remains to be determined. One unknown metabolite was observed. This compound accumulated to a much lesser extent in the microcosms prepared with both FeO and cells, consistent with the much higher degree of mineralization observed in these microcosms. The identity of the metabolite remains unknown thus it is of potential concern. In addition to iron enhancing bacterial activity, some bacteria also can enhance iron reactivity by reductive dissolution and activation of some oxides that passivate the iron surface. This enhancement may occur through three mechanisms: (1) reductive dissolution of Fe(III) oxide layers to uncover reactive FeO; (2) Generation of reactive surface associated Fe(II); and (3) Direct biotransformation of the target contaminant. It has been shown that iron barriers may be an effective approach to intercept and degrade RDX plumes and that some microorganisms can enhance the cleanup process by exploiting cathodic depolarization and pollution degradation as metabolic niches. Continuous flow columns were also used to evaluate RDX removal in flow-through systems mimicking a permeable reactive barrier. The steel wool column removed more that 98% of the influent RDX within the first sampling port, suggesting that PRBs used to treat RDX could be relatively thin. Initial RDX concentration profiles show extensive RDX removal in all columns with FeO and also some removal due to biological activity in the bioaugmented soil layer. Converging lines of evidence suggest that a concurrent or sequential combination of iron and biological treatment approach may be appropriate to intercept and destroy RDX plumes.

TRANSITION: This project will seek to collaborate with other scientists and contractors at DoD sites to conduct controlled field demonstrations. Possible sites for demonstrating this technology include the Iowa Army Ammunition Plant (IAAP) at Middletown, IA, and the Nebraska Ordnance Plant (NOP) in Mead, NB. Field technology transfer and trial will be pursued after obtaining a better understanding of the applications and limitations of the pertinent processes.

PROJECT SUMMARY

PROJECT TITLE & ID: In-Situ Remediation of Explosives Contaminated Groundwater with Sequential Reactive Treatment Zones; CU-1176 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Paul Tratnyek; Oregon Graduate Institute – Beaverton, OR

FY 2000 COMPLETED PROJECT

DESCRIPTION: The objective of this project was to develop a sequence of reactive treatment zones (SRTZ) for treating groundwater contaminated with nitrated compounds such at TNT, RDX, Tetryl, etc. The SRTZ consisted of (1) an Fe(O) permeable reactive barrier (PRB) to reduce nitro groups to amines, followed by (2) an oxidation cell that immobilizes the amines by oxidative polymerization. This project evaluated methods of treating the effluent from an FePRB by in situ chemical and/or enzymatic oxidation. Emphasis was placed on optimizing the (permanent) sequestration of nitrated compounds by oxidative polymerization and coprecipitation with iron oxides in an open cell. A variety of oxidants (air, O_2, H_2O_2), delivery systems (sparging, direct injection, passive infiltration), and process variables (flow rate, pH, carbonate, iron) were tested at the column scale. Design criteria for pilot and full scale SRTZs was developed using column test results and computer modeling.

BENEFIT: The project is designed to provide an efficient transition into one of two promising paths for further development of this technology: (1) a pilot-scale demonstration in the PRB test facility at the Oregon Graduate Institute, or (2) a pilot-scale field demonstration at a DoD field site. The latter may be preferred, but details cannot be established for such a plan until a site is selected and collaborations have been established with DoD/DOE scientists and engineers who are involved with the site. Some details can be provided, however, on how a pilot test could be preformed at one of OGI's LEAP tanks.

ACCOMPLISHMENTS: TNT remediation was achieved by zero-valent iron (ZVI) alone. Complete removal in 100% ZVI columns was observed with the capacity exceeding expectations. This treatment is a dynamic process yet simple, effective, and robust. Three publications and two presentations have been made based on this work. Future work will involve the following: (1) Continue loading 100% iron column to determine capacity. (2) Extract segments of column to determine distribution of TNT and products along the flowpath. (3) Begin design of scaled-up pilot test of a 100% iron wall for treatment of TNT. (4) Start preliminary tests with RDX and 100% iron column. (5) Continue looking for conditions where oxidation is effective at removing nitro reduction products.

TRANSITION: The project plans to transition into one of two promising paths for further development of this technology: (1) a pilot- scale demonstration in the PRB test facility at the Oregon Graduate Institute, or (2) a pilot-scale field demonstration at a DoD field site. The latter may be preferred, but details can not be established for such a plan until a site is selected and collaborations have been established with DoD/DOE scientists and engineers who are involved with the site.

PROJECT SUMMARY

PROJECT TITLE & ID: Statistical Methods and Tools for UXO Characterization; CU-1199

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Brent Pulsipher; Pacific Northwest National Laboratory – Richland, WA

FY 2001 FUNDS: $291K

DESCRIPTION: Many Formerly-Used Defense Sites (FUDS) are slated for clean up and transfer to the public for other uses. The risks associated with Unexploded Ordnance (UXO) in soils at the site are a significant concern. Risks must be managed to acceptable levels commensurate with hazardous clean-up activities and intended future use. There are two types of risks that must be considered. (1) Risk of unidentified UXO that could be inadvertently discovered during or after clean up or by future landlords resulting in hazardous lawsuits. (2) Risk of spending too many tax dollars on characterization with a non-optimal characterization scheme or when there is no real threat present.

This research team proposes a program that will evaluate and develop statistical methods and tools that can be used to develop characterization and verification plans and data evaluation schemes that will appropriately account for these two sources of errors. Significant research for UXO measurement system performance has been conducted and continues, including performance evaluations of Multi-Sensor Towed Array Detection Systems (MTADS) at Jefferson Proving Ground. Pertinent estimates of probabilities of detection and false positive error rates will be extracted from such programs. Although this proposed activity will incorporate these pertinent estimates of measurement error, our focus will be on the statistical sampling methodology, not the measurement performance.

A number of statistical sampling methods may be feasible including stratified sampling, adaptive sampling, proportional sampling, geostatistical/spatial sampling, or quasi-random sampling. Rather than recommend a specific methodology at this point in time, in keeping with the spirit of the DQO process, each of these methods will be evaluated early in the program to determine applicability and adaptability to the UXO characterization problem. Some methods may be most appropriate for defining contamination boundaries whereas others may be better for post-cleanup verification. Some methods may not lend themselves to modifications required by the particular constraints found with UXO characterization. The performance of acceptable methods relative to the two risks (cost and hazard) mentioned above will be evaluated. Once the methodologies are selected, statistical algorithms that are easy to apply or lend themselves to software implementation will be developed. Finally, prototype tools will be developed and demonstrated using existing data or as part of a characterization scheme on a particular UXO site.

BENEFIT: Although many UXO suspected sites may have a fairly small area where the UXO is expected, much of the surrounding area may have some UXO present. With the millions of acres surrounding some of these potential UXO sites, it is often cost and/or time prohibitive to conduct a 100% survey of the entire site. Thus statistical sampling must be employed to provide an acceptable level of confidence that UXO is not present in certain areas. It is envisioned that the statistical methods developed will provide a mechanism for developing sampling schemes that will result in an acceptable level of confidence that UXO is not an issue for certain portions of a site. The methods will allow the stakeholders to analyze the tradeoffs between sampling requirements and risk of incorrect decisions. A statistically based sampling approach could avoid significant costs of characterization. Specific payoffs will be the availability of methods and tools in the form of technical reports, publications, software, and presentations.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: The statistical methods and prototype tools developed under this project will be applicable to many users at DoD facilities where UXO is a concern. Statistical methodologies will be demonstrated using existing or simulated data or in conjunction with one or more actual UXO site characterization activities. Working with UXO site characterization managers and personnel to apply the methods will be an excellent opportunity for transitioning the expertise developed. Development of a prototype software tool will greatly enhance the transition of the methodologies to practice.

PROJECT SUMMARY

PROJECT TITLE & ID: Bayesian Approach to UXO Site Characterization with Incorporation of Geophysical Information; CU-1200

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Sean McKenna; Sandia National Laboratories – Albuquerque, NM

FY 2001 FUNDS: $224K

DESCRIPTION: The occurrence of unexploded ordnance (UXO) on DoD controlled sites is of critical importance as these sites are prepared for return to the public sector. Efficient characterization and remediation of UXO at these sites is necessary. The current practice of statistical characterization of UXO sites is based on classical statistical approaches derived from assuming the occurrence of UXO is the result of a Bernoulli process. This assumption does not allow for spatial correlation of the UXO density, and it is difficult to incorporate ancillary information provided by geophysical techniques and archival site records in an objective manner.

This effort describes an approach for the characterization of the intensity (density) of UXO across a site that can make use of archival site records and geophysical information. A doubly stochastic Poisson process defines the occurrence of UXO. The spatially varying intensity of this Poisson process can be estimated with spatial statistical algorithms. The result of this description is that the determination of the precise locations of any individual UXO in the subsurface will require sampling at that specific location. However, determination of the variable UXO intensity across a site does not require exhaustive sampling and can make use of less precise, or subjective information through a Bayesian updating approach.

Bayesian updating produces a map of the site displaying the probability of exceeding a specified clean-up goal. This probability of exceedence is the probability of failing to meet the clean-up criteria. A data worth framework is applied to the characterization/remediation alternatives being considered to optimize the sampling locations and determine the number of samples that lead to the lowest total project cost. This approach will be developed using an exhaustively known data set. The approach will be validated and compared to current UXO site characterization guidelines on a separate data set.

BENEFIT: This project will provide a new, validated, UXO characterization protocol that can be applied to DoD sites. This protocol will significantly improve currently available techniques used to characterize UXO sites by incorporating prior information through a Bayesian approach, by using geostatistical techniques to update that prior information, and by optimizing the characterization using a data worth approach. This protocol is designed to take advantage of the recent investment in detailed geophysical survey technology that has been made by SERDP and other branches of DoD. The overall benefit of this project will be to provide a more efficient and defensible protocol for the characterization of UXO sites.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: In the transition of this technology, it will be necessary to organize and implement a full-scale field demonstration of the characterization procedure developed. Initial planning of this field demonstration and a concise statement of the requirements necessary in a field site will be developed. The techniques and algorithms developed herein will be in the form of research software at the completion of this project. Translation of this research software into a user-friendly package that can be deployed at numerous sights will follow. Commercial vendors with experience in developing software under contract to DoD will be contacted and a technology transfer plan will be implemented.

PROJECT SUMMARY

PROJECT TITLE & ID: Spatial Statistical Models and Optimal Survey Design for Rapid Geophysical Characterization of UXO; CU-1201

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. W.E. Doll; Oak Ridge National Laboratory – Oak Ridge, TN

FY 2001 FUNDS: $311K

DESCRIPTION: Modern geophysical sensor array technologies are being used to fully characterize large potential UXO sites around the world. While the cost per acre for these array-based surveys is often an order of magnitude better than conventional ground surveys, the sheer size of the problem is such that the total end price is still untenable. Statistically valid sampling approaches need to be developed to further reduce the survey footprint.

The proposed approach makes use of the unique advantages of sensor arrays in order to reduce the required sampling area while removing the necessity for complete definition of ordnance distribution. Rather than dividing a homogeneous sector into small grids for detailed investigation (as is currently done in ground-based statistical surveys), a distribution of array swaths is proposed to delineate the boundaries of contamination with higher confidence and lower cost. When a regular pattern of swaths from a sensor array is employed, ordnance density within a sector can be directly mapped (rather than assumed to be uniform) as levels of contamination at a specific measure of uncertainty. This removes the statistical assumption of homogeneity within a sector and can form the basis for remediation decisions and risk assessment. This sub-sampling approach is applicable to any array of sensors collecting a swath of data, whether magnetic or electromagnetic, ground or airborne.

While the technology to conduct these surveys exists, the mathematical foundations and statistical protocols have never been developed. This effort will develop solutions based on the point process theory of spatial statistics. While the locations of UXO are described by spatial point pattern, these locations are not measured directly but are instead observed by an instrument in the proximity of the location (such as a magnetometer) that responds to a physical property of the UXO. Advanced geophysical modeling will be integrated into the study to translate statistical spatial models into measurable parameters.

Ultimately, the purpose of a statistical survey is to reduce the cost of clean up while retaining high confidence of lowering risk posed by UXO. Throughout the process, an assessment of practicability and reliability of the technology has been included. In advance of commitment to a project, confidence measurements are provided through geophysical modeling of targets and statistical modeling of their distributions. Similarly, cost reductions need to be measured in advance of a project. Airborne surveys, for example, have a unique set of operational conditions and cost drivers. In order to adequately set the scope of work for a statistical airborne survey and to calculate the associated cost-benefit-risk factors, a new set of criteria for evaluation needs to be developed alongside a new approach to airborne data processing and interpretation.

BENEFIT: The short-term benefits to DoD of this SERDP project include the development and demonstration of a statistically-valid survey methodology for large scale UXO detection and mapping that is technology independent; significant cost reduction for site analysis related to UXO characterization; and the availability of an analysis package to be used by members of the UXO community. The long-term benefits of this project are a potential reduction in the cost of UXO characterization on more than 25 million acres of contaminated land in the U.S.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: This project will provide a significant number of tangible products and results that will have direct and continued application to DoD and other ordnance-laden sites. The transition and dissemination of the results of this project will be accomplished through the DOE and DoD technology transfer programs, through participation of team members from the private sector, through presentations at symposia such as the UXO Forum, and through the publication of results in trade publications, peer-reviewed journals, and other scholarly publications. The commercialization of individual results, as well as the overall acquisition and statistical methodology, will be examined for transfer to the private sector during appropriate phases of the project, and an appropriate commercialization plan will be provided.

PROJECT SUMMARY

PROJECT TITLE & ID: Foam Delivery of Hydrogen for Enhanced Aquifer Contacting and Anaerobic Bioremediation of Chlorinated Solvents; CU-1203

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. George Hirasaki; Rice University – Houston, TX

FY 2001 FUNDS: $225K

DESCRIPTION: Hydrogen sparging of aquifers contaminated with chlorinated solvents has shown promise as a method to enhance microbial dechlorination in situ. The major concern in the application of this remedial approach is the ability to distribute hydrogen effectively throughout the contaminated interval such that complete dechlorination can occur. As is true for aerobic biosparging application, the horizontal and vertical extent of residual gas saturation formation during hydrogen sparging is limited to only a small, conical region around and above the screened interval because of the low density and viscosity of hydrogen compared to water.

A promising method to improve hydrogen contact throughout a contaminated interval and to greatly extend the horizontal migration of hydrogen in the subsurface is to deliver the hydrogen as an "in situ generated foam" - a dispersion of gas in water that is stabilized from coalescence by the presence of a small amount of surfactants. The objective of this effort is to investigate the ability of hydrogen-foams to more effectively contact aquifer sands thereby supporting rapid dechlorination activity compared to conventional hydrogen sparging. The foam is generated by injection of a slug of dilute surfactant solution into the well, followed by gas injection. The gas bubbles that form are inhibited from coalescence by the surfactant adsorbed at the interfaces, and the lamellae or "soap films" between the bubbles increase the resistance of the gas to flow through porous media. A previous field study has demonstrated that the use of foam greatly improves the extent of aquifer contacted by the injected gas.

BENEFIT: The expected benefit of hydrogen delivered as foam is increased well spacing and decreased frequency of sparging. A recent field test of hydrogen biosparging has showed the base of the aquifer not being contacted by hydrogen at a distance of 3 feet from the sparge well. A recent, foam assisted surfactant flood for DNAPL remediation showed the injected gas at the base of the aquifer 15 feet from the injection well. If foam can increase the distance that hydrogen contacts the base of the aquifer from 3 feet to 15 feet, the area of the base of the aquifer contacted by hydrogen may increase by a factor of 25. Alternatively, an aquifer can be remediated with 1/25 as many wells if foam improves the aquifer contact by the amount of this illustration.

Another potential benefit of foam is that it will increase the amount of residual hydrogen gas saturation after sparging. If the residual gas saturation is increased, a longer amount of time will pass before the hydrogen is depleted and sparging needs to be repeated. Thus, foam delivery of hydrogen may reduce the frequency of sparging per well. If the trapped gas saturation in the contacted region is increased from 10% to 50%, the frequency of sparging per well can then be reduced by a factor of 5. Combined with a reduced number of wells required to conduct the remediation, the frequency of sparging a well in the entire project can be reduced by a factor of 125.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: The studies proposed are designed to yield the information required for field applications. To facilitate the transition to the field, a conceptual design component has been included in the objectives. Additionally, results of the proposed work will be provided to DoD stakeholder and industrial affiliates for incorporation into ongoing cleanup projects. Site-specific design and site characterization for the use of hydrogen-based foams is beyond the scope of this project. Therefore, this project intends to transition through the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: Innovative Electrochemical Injection and Mixing Strategies for Stimulation of In Situ Bioremediation; CU-1204

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. R. Mark Bricka; USA - Engineering Research & Development Center –Vicksburg, MS

FY 2001 FUNDS: $200K

DESCRIPTION: The purpose of the first year effort is to demonstrate the ability of EK to transport amendments through low permeable soils in a timely fashion through a series of proof-of-concept experiments. If successful, the ultimate goal of the four-year proposal will be to demonstrate effective remediation in an in situ scenario at the pilot level. EK assisted amendment transport should have immediate transference to the demonstration/validation phase of testing and ultimate commiseration if the pilot study is successful. This research is based on the hypothesis that: (1) single-phase or dual polarity pulse direct current (dc) electric fields can be used to engineer strategies for transporting and thereby mixing contaminants, biosimulants, and possibly bioaugmentation inoculates to enhance in situ dechlorination of TCE in heterogeneous aquifers and leaky aquitards; and (2) the redox environments generated by electrolysis can be engineered as reactive zones that intercept TCE and enhance the dechlorination process. However, the process is complex. Through a multidisciplinary approach, basic research will be conducted to better understand the fundamental processes. Then, using a sequence of GO/NO-GO decision points, the technology will move towards pilot-scale field testing. To reach this end, three specific strategies have been developed followed by a field demonstration combining the successful strategies.

While the total scope of the project is comprehensive, this first year proof of concept effort is limited to providing evidence that electronkinetics (EK) can effectively assist the transport remediation amendments through low permeable soils. Evidence will be provided by evaluating additive transport and delivery rates, microbial activity and community structure under single-phase or dual polarity pulse dc fields. In addition, the TCE transformation kinetics and end products will be examined under similar conditions.

BENEFIT: The immediate benefits will be to demonstrate the transport of amendments in low permeable soils. This has been a limiting factor in the successful application of many in situ technologies. In the long-term, if successful it is anticipated that EK technologies will become an integrated part of most in situ treatment applications. EK assisted amended transport will enable current cost of clean-up technologies to be reduced thus providing a substantial cost avoidance. In addition, EK assisted amendment transport will enable in situ technologies to be applied in low permeable soils. Currently, most in situ approaches for low permeable soils are very costly or relatively ineffective.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: Actual data obtained from soil samples at DoD installations will be of direct interest of owners of these sites. Because the final product of this research will be a field pilot and supporting data, users and regulators will have the initial defensible data from a pilot field study necessary to approve larger field demonstrations. If this first year effort is determined to be successful by the SAB, a revised follow-on proposal will be submitted for project continuation.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Permeable Reactive Barriers Using Edible Oils; CU-1205

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Borden; North Carolina State University – Raleigh, NC

FY 2001 FUNDS: $135K

DESCRIPTION: Permeable reactive barriers (PRBs) are being considered at many sites because they are expected to have much lower operation and maintenance (O&M) costs than active pumping systems. As solvents or other contaminants migrate through the barrier, the contaminants are removed or degraded, leaving uncontaminated water to emerge from the downstream side. This project proposes to develop and evaluate an alternative barrier system for controlling the migration of chlorinated solvents. An oil-in-water emulsion will be prepared using food-grade edible oils and then injected into the contaminated aquifer in a barrier configuration using either conventional wells or Geoprobe points. As the emulsion passes through the aquifer, a portion of the oil becomes entrapped within the pores leaving a residual oil phase to support long-term reductive dehalogenation of chlorinated solvents that enter the barrier.

BENEFIT: Edible oil barriers have tremendous cost and operational advantages over competing technologies including zero valent iron barriers and anaerobic bioremediation using soluble substrates. Construction costs for zero valent iron barriers are typically in the range of $100 per square foot of barrier. In comparison, installation of a 40 ft deep by 200 ft wide edible oil barrier is estimated to cost less than $100,000 or approximately $15 per square foot of barrier. If the edible oil barrier technology can be adequately developed, this approach has the potential to significantly reduce the cost and improve the effectiveness of aquifer remediation for chlorinated solvents and a variety of other contaminants including nitrate, chromate, and oxidized radionuclides.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: Results of this research will be presented at research symposia and in peer-reviewed journals and will be shared with practitioners currently using the edible oil process at field sites. Three companies are conducting demonstrations of the edible oil process at Air Force Bases around the United States. Laboratory results obtained in this project will be implemented rapidly in the field demonstrations being conducted for AFCEE. These companies are also actively marketing the edible oil process to public and private clients. As a consequence, results will be rapidly communicated to the user community.

PROJECT SUMMARY

PROJECT TITLE & ID: Low-Volume Pulsed Biosparging of Hydrogen for Bioremediation of Chlorinated Solvent Plumes; CU-1206

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Charles Newell; Groundwater Services, Inc. – Houston, TX

FY 2001 FUNDS: $154K

DESCRIPTION: As a result of their widespread use as degreasers, solvents, and dry-cleaning agents, chlorinated solvents (e.g., PCE, TCE, etc.) are among the most prevalent of groundwater contaminants found at DoD sites. Laboratory studies have shown that the addition of hydrogen as an electron donor is effective in stimulating the biological reductive dechlorination of chlorinated solvents. The challenge in scaling up this technology for field applications is the effective distribution and mixture of the hydrogen with the contaminants in situ.

One promising method that has the potential to effectively mix hydrogen in contaminated groundwater is low volume pulsed hydrogen biosparging (LVPB-H_2). This technology has been partially evaluated by the project team in several lab studies and in one Air Force field test. The objective of this SERDP proposal is to further develop this innovative mixing approach by answering these key questions:

1. How much hydrogen gas can be pulsed into the subsurface safely?
2. What is the effective zone of influence of an LVPB-H_2 pulse?
3. How long do residual hydrogen bubbles persist before complete dissolution?
4. What are the reductive dechlorination rates that can be achieved using LVPB-H_2?
5. Is LVPB-H2 an effective DNAPL removal technology?

Experiments will be conducted at Rice University using the 5400 gallon (20,400 L) pilot-scale Experiment Controlled Release System (ECRS) developed by the DoD's Advanced Applied Technology Demonstration Facility (AATDF) for testing emerging remediation technologies. Use of this research apparatus will allow the project team to perform tightly controlled studies of hydrogen breakthrough, distribution, residence time, and the resulting dechlorination processes. Besides air and water sampling during the experiments, Time Domain Reflectometry (DR) equipment will allow the project team to visualize the migration and subsequent dissolution of hydrogen gas channels through the porous media. With the combination of sampling results and TDR data, fundamental process knowledge about low-volume pulsed biosparging with hydrogen will be developed.

BENEFIT: The immediate benefit of this work is a more fundamental understanding of hydrogen dissolution and transport in the unsaturated zone and its effectiveness in promoting reductive dechlorination of chlorinated solvent-impacted plumes. The results of this project will allow biosparging systems to be better designed once the radius of influence, hydrogen bubble-life time, and safety issues have been studied in detail. The Air Force has funded the initial development of hydrogen delivery technology and has achieved promising results from low-volume pulsed biosparging at one field site. This additional work will aid engineers in understanding the process fundamentals and in developing methods to best implement the process. In addition to the Air Force, the DoD as a whole benefits from the refinement of hydrogen biosparging technology.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: Hydrogen biosparging is a simple technology that will be easy to implement at a variety of military installations. Its configuration can be tailored to site-specific requirements, making it very flexible. For example, sparge points can be installed to act as a passive barrier to plume migration or a larger array of sparging wells can be installed for active plume remediation or source zone remediation. This technology involves a minimum of equipment and personnel, significantly reducing capital, labor, training, and maintenance costs.

PROJECT SUMMARY

PROJECT TITLE & ID: In Situ Stabilization of Persistent Organic Contaminants in Marine Sediments; CU-1207

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Richard Luthy; Stanford University – Stanford, CA

FY 2001 FUNDS: $500K

DESCRIPTION: This work addresses exploratory innovative technology development that builds on prior SERDP research on the binding and availability of hydrophobic organic compounds (HOCs) in sediments. The research team will investigate the feasibility for in situ stabilization/containment of persistent HOCs in sediments through the use of low-dose, coal-derived material, such as coke, as sorbent medial to sequester persistent organic contaminants. It is proposed that coal-derived material placed on or within sediment is a cost-effective, in situ, non-removal, management strategy. Recent study and past research have shown that coal-derived materials are strong sorbents that may capture organic contaminants and make them unavailable in the aqueous phase and unavailable for biological uptake. Coal-derived and coaly, particulate sorbent media are two-to-three orders of magnitude more efficient in sequestering HOCs compared to natural sediment organic matter. Thus, the addition of fresh coal-derived sorbents to contaminated sediments would reduce ecosystem exposure by reducing contaminant flux between sediments, pore water, and the water column. Owing to the extreme temperatures employed during manufacture, coal-derived sorbent media like coke is free of volatile materials such as polycyclic aromatic hydrocarbons (PAHs) and is therefore not a regulatory concern. For example, particulate coke is approved for direct bulk placement in the subsurface for pipeline cathodic corrosion protection. The research team will employ the most advanced scientific and engineering techniques to provide fundamental understanding of the physical, chemical, and biological phenomena relating to the efficacy of the proposed technology. It will investigate the feasibility of the technology for in situ stabilization of PAH and polychlorinated biphenyl (PCB) contaminants found in marine sediments. Navy collaborators will assist with site selection, sediment sampling, and information sharing.

Novel whole-sample, particle-scale, and subparticle-scale techniques that have been developed for sediment characterization will be used to assess the efficacy of the stabilization technology. These techniques allow one to identify the distribution and relative availability of organic contaminants among sediment component materials. In this way, the research team can monitor how effective the coal-derived material is at capturing and binding the readily available fraction of the PAH and PCB contaminants. The team will test various low-cost materials including coke and char and compare the results with those of activated carbon. Particulate coke is especially attractive because it is very inexpensive at less than $0.02 per pound. Thus, it has excellent economic feasibility and "transition potential." The research team will monitor the success of the stabilization process by spectroscopic and spectrometric measurements and by survival and growth of organisms currently used to develop chronic, sublethal, marine sediment bioassays for national regulatory programs.

BENEFIT: A number of DoD sites contain contaminated sediments. Hydrophobic organic compounds such as PAHs and PCBs are important contaminants of concern to the DoD. These contaminants associate with fine grained, organic-rich material in sediment and are long-lived. Sediment serves as a contaminant reservoir from which fish and bottom-dwelling organisms can accumulate toxic compounds like PCBs that are then passed up the food chain. Thus, cost-effective and efficient technologies for contaminated sediment management can significantly reduce the defense expenditure on environmental restoration and achieve the DoD environmental security goals and objectives. The potential benefit of this work is the attainment of in situ contaminant management by means of a cost-effective and non-removal technology resulting in stabilization to significantly reduce contaminant bioavailability.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: Results from this research will provide a proof of concept of the proposed in situ containment technology and a scientific basis for the support of field implementation of the technology. Successful completion of the research should lead to a future pilot scale demonstration project at a DoD marine site. Partners within this program will publish in peer-reviewed journals and will present information at national and international symposia and informal briefings at DoD, Navy, Army, USACE, and U.S. EPA offices. The results of this study will be presented in a series of USAE Waterways Experiment Station (WES) reports, utilizing a functional format to encourage demonstration and implementation beyond the proof of concept stage. The reports will include information such as process mechanisms, application protocol, process economics, technical points of contact, and process limitations.

PROJECT SUMMARY

PROJECT TITLE & ID: In Situ Enhancement of Anaerobic Microbial Dechlorination of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans in Marine and Estuarine Sediments; CU-1208

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Max Haggblom; Rutgers University – New Brunswick, NJ

FY 2001 FUNDS: $136K

DESCRIPTION: The management of marine and estuarine sediments contaminated with toxic organic compounds, including polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs), is a major problem with far-reaching economic and ecological consequences. Enhancement of microbial degradation of PCDD/Fs in situ is an attractive remediation alternative that could potentially detoxify sediments, avoid the problematic redistribution of contaminants that is associated with dredging, and decrease the cost of sediment management. Application of bioremediation to PCDD/F- contaminated marine and estuarine sediments is currently severely limited by the lack of fundamental knowledge about the microorganisms responsible for their degradation, including anaerobic reductive dechlorinated-the first step required for the ultimate complete degradation of highly chlorinated congeners.

The research team will characterize the PCDD/F dechlorinating capability of native dehalogenating bacteria from different estuarine and marine sites. Enrichments developed from these sites and an existing dioxin-dechlorinating culture will be used to assess how PCDD/F dechlorination can be stimulated and accelerated under different terminal electron accepting conditions (methanogenic, sulfate-reducing, and iron-reducing) relevant to marine sediments. A variety of intensive amendment strategies will be tested to enhance reductive dechlorination including addition of alternative halogenated primers such as bromophenols; co-amendment with hydrogen, hydrogen donors, and other electron donors; and manipulation of the terminal electron-accepting processes, e.g., by cycling enrichments through periods of sulfate excess and sulfate depletion in order to enrich for sulfate-reducing, dehalogenating bacteria. Enriched dehalogenating populations from different sites and under different redox conditions will be characterized using a combination of molecular methods, including cellular phospholipid fatty acid profiling and terminal restriction fragment length polymorphism (TRFLP) 16S rRNA gene fingerprinting. TRFLP will be combined with cloning sequencing of 16S rRNA genes to identify the organisms represented by the TRFLP peaks. Identification of the major microbial members in PCDD/F-dechlorinating communities will allow better understanding of successful strategies and formulation of new strategies for enhancing dechlorinating activity.

BENEFIT: Treatment of contaminated marine and estuarine sediments in-situ is an attractive remediation alternative because of the likelihood of reduced cost and ecological impact. One important class of compounds that are regulatory targets in near-shore sediments is the highly toxic polychlorinated-dibenzo-p-dioxins and -furans (PCDD/Fs). Microbially-mediated dechlorination of PCDD/Fs is known to occur, but fundamental information about the microorganisms involved is lacking. The immediate and direct benefit to SERDP from this project is a fundamental understanding of dehalogenating bacterial communities that dechlorinate PCDD/Fs in marine and estuarine sediments and how these communities are affected by redox conditions and addition of primers and amendments. Data collected from enrichments and the accompanying microbial community characterization will be used for the development of conceptual and biological process models to describe and predict the effect of different enhancement methods on the terminal electron accepting process and microbial populations. These findings will result in development of methodologies for the assessment of the potential for PCDD/F dechlorination at specific sites. These methodologies could ultimately result in significant savings for costly sediment restoration projects now faced by the Department of Defense. The long-term potential benefit to SERDP is the eventual application of the developed in situ amendment strategies in pilot or small field-scale experiments.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: This project will develop methodologies for monitoring in situ bioremediation of contaminated sediments. The specific technologies developed will include the identification of specific amendments and environmental conditions that prime and/or accelerate the dechlorination of PCDD/Fs. The study will also develop methodologies for assessing the potential for dechlorination at a specific site. Peer-reviewed articles and conference presentations will be used to transfer findings to the scientific community for possible future application.

PROJECT SUMMARY

PROJECT TITLE & ID: Pathway Interdiction: A System for Evaluating and Ranking Sediment Contaminant Transport Pathways in Support of In-Place Management; CU-1209

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Sabine Apitz; Space & Naval Warfare Systems – San Diego, CA

FY 2001 FUNDS: $497K

DESCRIPTION: Many of the contaminated marine sediment sites which are currently under investigation are in shallow, coastal areas and are much more likely than more traditionally studied offshore sediments to be impacted by advective processes such as groundwater flow, tidal pumping, wave pumping, and by resuspension via ship and storm activity. While these processes are recognized in the oceanographic community as having significance to chemical fluxes, they are largely unstudied in contaminated systems, and the relative magnitudes of these processes as compared to the traditionally assessed processes such as diffusion and bioturbation have not been determined.

In this effort, the range of in situ sediment management options is defined as a continuum - beginning with those requiring no containment or physical control (those which are to allow natural attenuation or biodegradation or more engineered in-place treatments), through simple or thin caps, and ending with more aggressive capping and containment technologies using armor, geofabric, or other sediment or contaminant controls. In essence, in-place sediment management consists of "pathway interdiction" while ex situ approaches represent mass removal. If contaminants are to be left in place, it is critical to evaluate potential pathways by which contaminants might pose an ecological or human health risk and to monitor, minimize, or eliminate these pathways.

This effort seeks to apply an integrated suite of methods for the direct characterization of these dynamic transfer pathways for contaminants in sediments. Methods for the quantification of mechanisms, magnitudes, and directions of porewater-mediated contaminant transport will be integrated with sediment/contaminant geochemical characteristics, hydrodynamically-driven particle transport, and biological processes. While each of these processes has been examined individually, they have never been examined together such that they can be ranked and compared to support in-place sediment management.

The proposed methodologies comprise a range of existing and developmental techniques which individually provide answers to specific questions, but when integrated have the potential to optimize management and decision making. The project goals, based on a successful integration of these approaches, will be to provide (1) an integrated suite of measurement techniques to characterize critical contaminant transport pathways for in-place sediments; (2) a corresponding set of indices that quantify the transport phenomenon on a common dimensional scale; and (3) a site-specific ranking methodology to optimize the selection of implementation of in-place remedial actions and to monitor the efficacy of such actions.

BENEFIT: U.S. EPA identified 96 watersheds in the United States as having areas of probable concern for sediment contamination. The cost to remove such sediments nationally has been estimated by the Sediment Management Work Group (SMWG) in 1999 to be in excess of five trillion dollars. The Navy estimate for contaminated sediment sites cleanup cost to complete is greater than $500 M. There are 110 facilities with identified sediment contamination, 48 facilities with high relative risk (NAVFAC NORM database), and most likely many others yet to be identified.

Given the economic, logistical, technological, and ecological limitations of removal and treatment technologies, it is inevitable that some contaminated sediments will be managed in place, in the short or the long term, even if contaminants pose some ecological or human health risk. However, leaving sediments in place has met with regulator and public resistance at many sites due to concerns about the long-term risk to the marine environment. It is assumed that the management process will seek to balance two parallel goals: (1) minimizing contaminant risk to the environment and human health, and (2) minimizing cost. A set of diagnostic tools for characterizing and quantifying potential in-place contaminant pathways will aid in the selection, permitting and monitoring of in situ management strategies. The payoff for a demonstrated, systematic process for measuring and evaluating contaminant transport pathways within sediment systems in support of in-place management will be twofold (1) by providing solid, measurement-based information on contaminant fate which results in the permitting of in place management, the savings can be millions of dollars per site, and (2) since pathways of contaminant transport in place can be directly measured, the ecological risk of leaving sediments in place will be reduced.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: Technology transfer will proceed in a number of directions: (1) Site-specific and pathway-specific information will be disseminated via peer-reviewed journals, professional scientific and technical meetings, and technical reports, (2) All work will be carried out at sites undergoing remedial investigation or management, in direct collaboration with RPMs, regulators and stakeholders, allowing for external review of the applicability of results and more rapid acceptance by regulators, (3) Work will be carried out in collaboration and communication with the EPA's National Risk Management Research Laboratory which has a number of related initiatives. Data generated will be made available for the NRMRL model being developed to predict sediment contaminant transport, (4) Dr. Apitz represents the Navy on the EPA-sponsored Remediation Technology Development Forum, Sediment Working group and the SMWG. Both groups seek to develop new technologies, and to provide input on sediment issues to the policy and regulatory community. Results of this project will be made available to these groups for review and use, (5) On top of the site-specific reports, a technical manual or guidance document will be generated, and (6) A Conceptual Design for an Integrated Transport Instrument will be generated, which will include those components demonstrated to be critical in determining transport indices. This project intends to transition through the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: Determining the Bioavailability, Toxicity, and Bioaccumulation of Organic Chemicals and Metals for the Development of Eco-SSLs; CU-1210

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Roman Lanno; Oklahoma State University – Stillwater, OK

FY 2001 FUNDS: $387K

DESCRIPTION: The goal of the proposed research is to identify and characterize the predominant soil physical/chemical parameters that modify the bioavailability, bioaccumulation, and/or toxicity of trinitrotoluene (TNT), trimethylenenitramine (RDX), polynuclear aromatic hydrocarbons (PAH), and selected metals in soil invertebrates and plants. Exposure concentrations will be measured as total chemical levels and as the labile portion that is presumed to be bioavailable. Both of these chemical measures will be correlated with toxicity endpoints (e.g., growth, reproduction) and bioaccumulation with the ultimate goal of developing models relating soil chemistry parameters to bioavailability, bioaccumulation, and toxicity.

The following technical objectives will be addressed in this research: (1) Examination of the effect of varying soil physical/chemical characteristics (e.g., organic matter content, pH, clay content) on the bioaccumulation and toxicity of TNT, RDX, and PAHs in plants and soil invertebrates; (2) Examination of the effect of varying soil physical/chemical characteristics on the bioaccumulation/transfer of selected metals from soil to invertebrates and plants; (3) Measurement of the exposure concentration of these contaminants in soil by different methods, such as solid-phase microextraction fiber (SPME), C18 EmporeT disk, neutral salt extraction and standard vigorous extraction methods for total chemical levels, to determine if techniques perceived to measure the bioavailable fraction of chemicals in soil are better correlated with bioaccumulation and toxicity than total chemical measures; and (4) Development of general models, based upon empirical relationships established during these studies, relating soil physical/chemical properties to the bioavailability, bioaccumulation, and/or toxicity of TNT, RDX, PAHs, and selected metals.

BENEFIT: The proposed research will benefit SERDP in multiple ways. Development of an empirical model relating soil physical/chemical characteristics to the bioavailability, bioaccumulation, and toxicity of TNT, RDX, PAHs, and selected metals to soil invertebrates and plants will allow the incorporation of bioavailability into the development of EcoSSLs by facilitating estimation of bioavailable levels of chemicals from literature data where only total chemical and soil physical/chemical characteristics are presented. Current chemical methods for estimating bioavailability have been correlated with biological responses of macroinvertebrates and plants in very few studies. The proposed research will develop these correlations for PAHs, TNT, RDX, Pb, Zn, Cd, and As and a number of soil invertebrates and plants, thereby validating chemical estimates of chemical bioavailability in soils. Validation of chemical measures of bioavailability would provide another tool that can be used in early-tier screening of contaminated soils during ecological risk assessment. The proposed research will also generate a large data set consistent with respect to QA/QC procedures and data criteria that can be used to develop EcoSSLs for the rapid initial screening of contaminated DoD, DOE, and EPA sites. This will allow the removal of low-risk sites from further ecological risk assessment and allow efforts and resources to be focused on sites that present an unacceptable risk to ecosystems. By screening out sites early in the ecological risk assessment process, a significant cost avoidance in the unnecessary cleanup of low risk sites will be realized.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: Both principle investigators are involved with the U.S. EPA Steering Committee for the development of Ecological Soil Screening Levels (EcoSSLs) and could therefore provide a direct conduit for the application of data generated during this research in the development of EcoSSLs. In turn, EcoSSLs generated with data provided from the proposed work could be used in the screening of soil contamination at DoD sites.

PROJECT SUMMARY

PROJECT TITLE & ID: Bacterial Degradation of DNT and TNT Mixtures; CU-1212

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Rebecca Parales; University of Iowa – Iowa City, IA

FY 2001 FUNDS: $306K

DESCRIPTION: The major objective of this effort is to characterize bacterial strains with the ability to efficiently degrade mixtures of dinitrotoluene (DNT) isomers and to expand the degradative capability to include 2,4,6-trinitrotoluene (TNT). Because most contaminated sites contain mixtures of nitroarene compounds, such strains would have the potential for use in the bioremediation of field sites. This research team has isolated bacteria that can degrade both 2,4- and 2,6-DNT and will carry out physiological and genetic studies with those strains to determine whether the DNT isomers are degraded simultaneously or sequentially and how the genes encoding the pathways are regulated. The pathways, enzymes, and inducing molecules will be characterized. Directed evolution studies with cloned nitroarene dioxygenase genes will generate enzymes with the ability to oxidize TNT. Team members will characterize the novel enzymes and the product(s) of TNT oxidation and screen for ring cleavage enzymes that can destroy the oxidized TNT molecule. If necessary, they will select for mutant ring cleavage enzymes that have the desired activity. The TNT dioxygenase and appropriate ring cleavage dioxygenases genes will be introduced into strains that degrade both isomers of DNT. The resulting strains will be tested for the ability to eliminate the toxicity of synthetic mixtures of DNT and TNT. The strains will be inoculated into microcosms containing contaminated soil from Volunteer Army Ammunition Plant and the degradation of DNT and TNT will be monitored. The research team anticipates that the results of these studies will lead to the development of new strategies for the clean-up of sites contaminated with mixtures of nitroarene compounds including TNT.

BENEFIT: Extensive contamination by DNT exists at Badger Army Ammunition Plant and at Volunteer Army Ammunition Plant. The cleanup at Badger is estimated to cost $275 million and site managers are currently searching for novel in situ bioremediation strategies. Bioremediation is being considered as the first choice for cleanup of the site even though several questions remain about the fundamental process. Biostimulation, bioaugmentation, and natural attenuation are all under investigation. The current pilot-scale project involves bioaugmentation with isolates adapted to the conditions at Badger. Bioremediation is expected to reduce the cost of remediation by $60M over previous estimates for the Badger site. Although preliminary results are encouraging, there is an urgent need to understand the regulation and degradation of mixtures. Previous experiments have revealed that 2,4-DNT could be degraded readily in soil and water from Volunteer although TNT and 2,6-DNT were problematic. The new insight about degradation of mixtures including TNT will be directly applicable to the future cleanup at Volunteer and at other TNT manufacturing sites. The research team proposes to generate recombinant organisms for the degradation of nitroarene compounds although field application of the basic discoveries to be made under this project is several years away. The release of genetically engineered organisms is becoming more and more common. To date, dozens of field trials utilizing strains of genetically engineered bacteria have been carried out in the U.S. Cleanup of in situ and excavated soil both in the U.S. and abroad should benefit considerably from novel microbial strategies for TNT and DNT degradation

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: Based on past and ongoing collaboration with multiple nitroaromatics contaminated sites, it is apparent that gains achieved by the research team will be rapidly incorporated into ongoing cleanup strategies and implemented in new cleanup efforts - particularly at Badger and Volunteer. The fundamental understanding about the degradation of DNT gained in this project will be immediately incorporated into the ongoing strategy for cleanup at Badger Army Ammunition Plant. It will serve as an enabling technology for the eventual cleanup at Volunteer Army Ammunition Plant where soil and groundwater are extensively contaminated with mixtures of TNT and DNT and where remediation has not been initiated. Furthermore, two private companies have recently contacted the research team to explore the feasibility for cleanup of DNT contaminated industrial sites.

PROJECT SUMMARY

PROJECT TITLE & ID: Microbial Degradation of RDX and HMX; CU-1213

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jalal Hawari; Biotechnology Research Institute – Montreal, Quebec CANADA

FY 2001 FUNDS: $370K

DESCRIPTION: Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) are powerful highly energetic chemicals whose widespread use has resulted in severe soil and groundwater contamination. Efforts over the past two decades to decontaminate soil and groundwater by biological means have failed because the microbial processes and enzymes involved in degradation are poorly understood. Recently, this research team has discovered that both RDX and HMX can be mineralized under both aerobic (P. chrysosporium and the soil isolate Rhodococcus sp.) and anaerobic conditions (municipal anaerobic sludge) to nitrous oxide and carbon dioxide despite some previous reports that RDX is not mineralized under these conditions. For example, it has been demonstrated that once RDX undergoes an initial biological attack the molecule autodecomposes. The mechanism leading to mineralization is unknown; however, several testable hypotheses exist regarding how mineralization proceeds. This team would like to test these hypotheses by conducting fundamental laboratory experiments to identify the enzymes that cause the molecules to disintegrate and to investigate the subsequent biochemical decomposition reactions. In addition, the team will identify intermediate degradation products and study the kinetics and stoichiometry of their formation. When the nature of the degradation mechanisms are known, this knowledge can be used to enhance bioremediation and to scale up the process for field application. Although the immediate interest is to understand the process in liquid media, the research team also proposes to conduct similar experiments in soil to determine the effect of soil type on the degradation process.

BENEFIT: Although the proposed research is intended to generate the fundamental knowledge needed to understand the enzymatic processes involved in the microbial degradation of RDX and HMX, the results can be used to enhance bioremediation and facilitate future field application. When the specific degrader(s) and enzyme(s) (reductase, hydrolase or oxygenase) responsible for the initial reaction on the cyclic nitramine explosive in liquid media are discovered, it will be possible to design effective field treatment strategies. Therefore, the inclusion and the design of bench scale experiments using soil from contaminated sites will generate the necessary knowledge required for future field demonstration and application. For example, knowledge of degradation mechanisms will allow prediction and enhancement of biodegradation in the site. Insight regarding microbial and enzymatic processes together with their degradation products can be used by site managers and engineers as monitoring tools to understand the fate of explosives after removal.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: Successful lab-scale microcosms for the degradation of RDX and HMX can provide the basis for pilot scale up work to identify engineering parameters for field demonstration and application. Results of this project will be disseminated in such a manner as to facilitate future investigations.

PROJECT SUMMARY

PROJECT TITLE & ID: Novel Pathways of Nitroaromatic Metabolism: Hydroxylamine Formation, Reactivity, and Potential for Ring Fission for Destruction of TNT; CU-1214

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Joseph Hughes; Rice University – Houston, TX

FY 2001 FUNDS: $313K

DESCRIPTION: Independent studies conducted by members of this research team have recently converged at the discovery of a similar and novel metabolic pathway that yields products from TNT that no longer display aromatic characteristics. The transformation rates observed via the novel pathway are rapid, and stimulation of activity does not require the high level of amendments used in current ex-situ TNT biotreatment systems (e.g., composting or slurry reactors). It should be possible to exploit this pathway in the development of improved TNT treatment methods, where the destruction of TNT is achieved and the process is carried out in situ.

The development of in situ bioremediation processes for the treatment of TNT and other nitrated compounds would greatly improve DoD's ability to restore contaminated sites in a more cost-effective manner. The factor that has limited the development of in situ bioremediation processes for treatment of TNT contaminated soils or groundwater is the inability of bacteria to use TNT as a growth substrate. For this reason, current ex-situ treatment systems (i.e., composting and slurry reactors) have focused on cometabolic transformations that lead to binding (also referred to as sequestration or humification) of metabolites to soil and amendments. This approach to TNT bioremediation does not result in ring fission, and because the products are difficult to characterize or monitor, the treatment endpoint remains controversial. In any case, the application of similar techniques for in situ treatment is unlikely as these processes use overwhelming amounts of co-substrate in heavily engineered systems to maintain very low redox potentials for extended periods. It has been suggested that partial reduction under anaerobic conditions can lead to binding and humification during subsequent aerobic treatment. The amount of carbon source and electron donors required are still daunting and the treatment does not result in destruction of the aromatic ring.

The goals of the proposed effort are to determine the biochemical mechanism of TNT ring fission and to use this fundamental information to develop strategies that harness the activity in remediation systems. Specific objectives of the proposed research are to: (1) Identify the products of the novel TNT transformation pathway that no longer display aromatic characteristics, (2) Determine the mechanism of ring fission and identify the enzymes responsible, (3) Characterize the properties of the enzymes and their regulation, (4) Develop strategies to direct TNT metabolism to ring fission products, and (5) Validate the destruction of TNT in lab-scale microcosm testing where mass balances and toxicity reduction can be determined.

The proposed studies will yield an improved understanding of the microbial processes involved in the degradation of nitroaromatic compounds. The research team believes that it will be important to extend fundamental discoveries to a "proof-of-concept" level and proposes laboratory microcosm studies as a link to the development of field applications.

BENEFIT: Based on the initial work by the research team, it should be possible to develop in situ treatment methods where the destruction of TNT is achieved. Strategies involving reduction only to the hydroxylamine level with subsequent rearrangement and ring fission would require far less carbon addition and less dramatic shifts in redox potential than conventional strategies for TNT cometabolism (the reaction sequence in Pseudomonas works even under aerobic conditions). The proposed strategy would therefore be considerably less energy intensive and would be much more amenable to in situ applications. It will also produce far less biomass and will lead to destruction of the aromatic ring of TNT. The potential to drive TNT to non-aromatic endpoints has been demonstrated in two widely different microbial systems, and it occurs at high rates. If demonstrated that this novel metabolism can be induced and sustained in situ, the development of low-cost remediation systems will be possible. Currently, no such technology exists for the DoD to use in the management of diffuse TNT contamination in soils.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITIION: Laboratory microcosms will be conducted with soils from the Volunteer Army Ammunition Plant and from the Alabama Army Ammunition Plant. Results of the proposed work will be provided to collaborators for incorporation into ongoing cleanup projects. Optimization of all the parameters for engineering design of the process is beyond the scope of this proposal. This project intends to transition through the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: EM-61-3D Discrimination of UXO Using Empirical, Analytical, and Numerical Models (*SEED project*); CU-1215

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Grimm; Blackhawk Geometrics, Inc. – Golden, CO

FY 2001 FUNDS: $95K

DESCRIPTION: This research project intends to explore optimization of model-based algorithms for UXO discrimination. Model-based approaches seek to recover physical properties of the target itself (size, shape, orientation, position) and therefore are most useful for target classification. However, there are strong trade-offs between model accuracy and efficiency. Models will be tested on existing data acquired by the EM-61-3D, a multicomponent, multichannel pulsed-induction sensor that provides more information than any other readily available electromagnetic instrument.

The team will directly compare three approaches to electromagnetic-induction modeling of discrete conductors, quantifying the accuracy and efficiency of each as functions of target size, shape, position, and orientation, A semi-empirical method treats targets as a group of infinitesimal, orthogonal dipoles and constructs responses for arbitrary position and orientation through linear superposition. Classification can be improved by experimentally determining the directional responses of targets of interest. The technique is very fast but is limited to distances relatively far away from the source and receiver, assumes no environmental effects, and can require prior data for each object to be classified. An semi-analytic theory is relatively fast, models the full field at arbitrary distances, and can include ground conductivity, but restricts target shapes to solid triaxial ellipsoids. Numerical models such as the finite-element method offer the most accurate solutions for arbitrary objects and environments but are slow, unsuited to parameter estimation, and require that responses from all potential targets be cataloged. The team proposes to test these three models on existing EM-61-3D test-bed data. If the numerical model is sufficiently accurate, it can be used to generate synthetic data to further define the parameter-space limits to accuracy of the other, approximate models.

BENEFIT: The project will quantitatively assess the relative merits of model-based discrimination methods, emphasizing the trade-off between speed and accuracy. Analysis of geophysical surveys for UXO is unlikely to be real-time in the foreseeable future, but the requirement for next-day turnaround is increasingly common. The results of this work will determine whether a sufficient database for the empirical models can be accumulated, whether a database of numerical model results needs to be generated, or whether the compromise semi-analytical theory can adequately address the requirements for both speed and accuracy.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: A full research program following this proof-of-concept study would expand to improved modeling of real UXO and scrap under a greater variety of positions, orientations, and environmental conditions. A follow-on effort would combine test-bed measurements and numerical modeling to define the limits to the empirical and analytical models for a complete range of target sizes and shapes. These techniques will also be useful for optimum sensor design for UXO discrimination. The utility of horizontal-field components and the slightly different time range that distinguish the EM-61-3D from the EM-63 will be assessed in the present work. Future work could study more generally the distribution of time gates required to recover shape parameters for UXO. Real field systems are also required to cover as much ground in as little time as possible. However, sensor move-out must be small compared to target distance over a period of time given by the base period times the number of stacks desired, which in turn affects the maximum time range and the S/N. Clearly, there will be a trade-off between survey speed and modeling accuracy, both of which affect cost.

The results of all of the research posed here will quantify the accuracy of the empirical and analytic models as functions of target size, shape, position, and orientation. One or both of these models and the appropriate sensors will be transitioned to fielded systems such as MTADS (enhanced for multichannel and/or multicomponent ability), thus enabling the step from detection to discrimination.

PROJECT SUMMARY

PROJECT TITLE & ID: UXO Data Analysis *(SEED project)*; CU-1216

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Dexter Smith; Johns Hopkins University – Laurel, MD

FY 2001 FUNDS: $100K

DESCRIPTION: Current sensor systems can detect and localize buried metal objects of a wide range of size and depth. These sensors typically measure the active and/or passive magnetic properties of buried metal objects. In some cases, the sensor measures the dielectric contrast of the buried object (i.e., ground penetrating radar). While current sensor technology has shown the ability to detect these buried objects, the false alarm rate is high because it tends to fail in discriminating the UXOs from metal objects that pose no risk. The development of discrimination algorithms is needed to reduce these false alarms and thus reduce the cost of UXO remediation.

The project objective is to is to develop algorithms to provide a robust capability to discriminate UXOs from clutter using wide bandwidth electromagnetic induction (EMI) sensor data. Two approaches will be used:

- Develop a technique for target discrimination that combines the spatial and eddy current decay data from buried metal targets. This work will be an extension of the EMI time-domain identification techniques developed for the U. S. Army Countermine Program.

- Apply a unique holographic algorithm for imaging the 3-dimensional electromagnetic field beneath the surface using the EMI sensors to determine the location, orientation, and size of the buried metal object.

The algorithms developed in this project will improve the utilization of EMI sensor data for the discrimination of UXOs. In addition to UXO remediation work, the algorithms may prove to be useful for buried utility localization or other commercial survey work.

BENEFIT: The goal of the target discrimination algorithms is to reduce the false alarm rate (FAR) associated with the use of time-domain EMI type sensors. A 50% improvement in the FAR will mean 50% fewer non-UXO targets excavated. This will translate into reduced remediation time and subsequent lower costs.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: For intellectual property (IP) generated under this effort, the government will be granted a no-cost license consistent with Federal funding statutes and regulations. Additionally, JHU/APL will seek to transfer the technology to the commercial sector by offering standard nonexclusive or exclusive licensing arrangements. Assessing technology insertions opportunities into existing UXO detection programs will follow the systems engineering trade study approach. Here performance, schedule, cost, and risk of the new technology or combinations of technologies will be examined and presented to government program managers. Concepts of operation for each program platform will be examined for compatibility with any technology improvements recommended for inclusion.

PROJECT SUMMARY

PROJECT TITLE & ID: A Unified Approach to the Processing and Fusion of Time and Frequency Domain EMI Data for UXO Discrimination *(SEED project)*; CU-1217

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Eric Miller; Northeastern University – Boston, MA

FY 2001 FUNDS: $75K

DESCRIPTION: In the past decade, significant effort has been devoted to the processing of time and frequency domain electromagnetic induction (EMI) data for detection and classification of buried unexploded ordnance (UXO). Many of the methods employ a physical model for the scattering of low frequency electromagnetic fields from UXO-type objects within a statistical signal processing framework. While a number of physics-based statistical approaches to the discrimination problem have been proposed, none adequately addresses the issues of uncertain object position and orientation or the processing of spatial information to the extent believed possible.

The objective of this project is to better understand the utility of time domain and frequency domain EMI data for UXO discrimination and to develop algorithms that optimally make use of both classes of information when the position and orientation of the object are uncertain.

The critical issues to be addressed during this effort involve the development and validation of statistical processing methods based on simple yet accurate, physical models which will allow UXO to be successfully discriminated from clutter when the position and the orientation of the object are not known with certainty and given data from time and frequency domain sensors collected at arbitrary points in space. Additionally, methods for fusing EMI sensor data will be examined to determine both how this might be done and whether there is significant performance benefit from such fusion. Further development would be warranted should these methods prove capable of high rates of successful classification with low rates of misclassification as demonstrated using real sensor data.

BENEFIT: The computation complexity of both the models and the processing schemes is relatively low. It is anticipated that a Matlab implementation running on a Pentium machine should produce discrimination results from data in the range of one to five minutes. The speedup using a C or Fortran implementation implies that our methods will be well suited for use in the field in conjunction with state-of-the-art sensors. The primary cost of further development is the coding of the methods in a lower level language than Matlab and the incorporation of these codes into existing systems. The primary benefit will be improvements in the discrimination of UXO from clutter.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: Transition opportunities exist with DoD/DOE associates such as Geophex, GeoCenters, EG&G, NRL, and Coleman all of whom make use of EMI sensors and all of whom would potentially benefit from the work done under this project. The principal investigator has worked with the first three members of this list and has current collaboration underway with EG&G on a GPR-related processing project.

PROJECT SUMMARY

PROJECT TITLE & ID: Inexpensive Chemiresistor Sensors for Real-Time Ground Water Contamination Measurement *(SEED project)*; CU-1218

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Hughes; Sandia National Laboratories – Albuquerque, NM

FY 2001 FUNDS: $100K

DESCRIPTION: The chemiresistor is a particularly simple type of chemical sensor. It relies on the change in conductivity of an organic or inorganic material in response to an analyte. With modem photolithography techniques, it has become possible to fabricate arrays of interdigitated electrodes on a planar surface, such as silicon nitride on a silicon chip, that may or may not contain electronic circuit elements. Sensors for organic solvent vapors are required for the detection of leaks, toxic chemicals, explosives, and solvent spills. As part of a system, these sensors need to be highly sensitive to small concentrations of vapors in the ambient air, while consuming minimal power for use in portable or remotely located devices and in long term monitoring applications. Such a sensor system must be able to quickly and reproducibly distinguish solvents from the ambient relative humidity - classifying the responses as a particular solvent, relative humidity, a mixture, or an unknown.

The chemiresistor technology that this research team has developed over the last 3 years has been focused on the gas phase detection of many VOCs. Previous experience has yielded the ability to fabricate arrays of different chemiresistors and to use the patterns of response to identify individual VOCs. The technical objective of this project is to demonstrate that the Sandia chemiresistor arrays can be packaged in such a way that they can be submerged in the aqueous phase and measure dissolved VOCs at low levels.

BENEFIT: The chemiresistor technology has been carried to the point of a manufacturable product by past internal Sandia funding. The ability to batch process many chemiresistors on a single silicon wafer at the same time with a computer controlled dispenser means that unit cost can be brought down below a dollar per sensor for large volumes of sensors. A manufacturable packaging technology will have to be derived from the successes of the first year of this project. This project does not address the data acquisition system to be used outside the water environment, but since the circuit gives a DC output proportional to the sensor signal, almost any common data acquisition system can be used. It is suspected that in many cases there will be requests to measure concentrations of contaminates at levels below 1000 times lower than the solubility, perhaps even a million times lower. A bare chemiresistor will probably not be able to detect reliably at those low levels. One suggestion for advanced development would be to couple a miniature preconcentrator chip with the chemiresistor. Preliminary data in a gas phase system has shown that the preconcentrator can deliver 10 to 1000 times the signal from a given analyte depending on the preconcentration time. This would make a more expensive and complex monitoring head to be immersed in the water, but it would still be smaller than matchbox size if Sandia’s micromachined preconcentrator was used. This system would also have the advantage of a means to correct for baseline drift of the chemiresistor.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: The ability to sense VOCs with the sensor head immersed in water (or other liquids) would add new capabilities for potential licensees of the multi-faceted chemiresistor technology being developed by the research team. The DoD/DOE would benefit from having an inexpensive technology for real-time monitoring of groundwater.

PROJECT SUMMARY

PROJECT TITLE & ID: Shear-Horizontal Surface Acoustic Wave (SH-SAW) Chemical Sensors for In Situ Characterization and Monitoring of Trace Organic Contaminants in Aqueous Environments *(SEED project)*; CU-1219

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Richard Cernosek; Sandia National Laboratories – Albuquerque, NM

FY 2001 FUNDS: $100K

DESCRIPTION: Chemical sensing systems based on arrays of shear-horizontal surface acoustic wave (SH-SAW) devices have potential for continuous, long-term monitoring of ground water contamination at DoD cleanup sites. Sensor arrays consisting of just a few SH-SAW devices with sensitive, chemically diverse coatings coupled with robust pattern recognition can both identify and quantify volatile and semi-volatile organic contaminants with detection limits well below regulatory levels. The use of shear-mode acoustic sensors allows for direct detection of chemicals in the liquid phase (as well as the vapor phase), unlike many other sensors that must operate in the vadose zone or that utilize membrane separators. The proposed sensors provide for in situ placement and rapid, reversible, and real-time (few second sample intervals) monitoring operation. Fully developed sensing systems are expected to be small, inexpensive (< $1000), and low power so that unattended, multi-point site monitoring is easily implemented.

The objective of this proposed research is to develop a small array of SH-SAW sensors and demonstrate, on a laboratory scale, the identification and quantification of trace volatile organic compounds (VOCs) in water. This effort will involve: (1) optimization of the SH-SAW devices as a transduction platform for liquid-phase chemical sensing; (2) selection of appropriate chemically sensitive coating materials for the target analytes; (3) preparation of coated SH-SAW devices and sensor characterization in aqueous environments; and (4) implementation of the visual empirical region-of-influence (VERI) pattern recognition algorithm for array optimization and analyte identification.

BENEFIT: Several research issues will be addressed during the course of this development project. They include the optimization of single SH-SAW devices for aqueous-phase chemical detection, the improved sensitivity of acoustic sensors for trace analyte detection in water, and the assembly of SH-SAW sensors into simple arrays to identify single analytes in water from a selected test group.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: Many research issues associated with this technology will remain after the proof-of-concept effort. These include detection and discrimination among binary analyte mixtures and multi-component mixtures in water, the effects of high concentration chemical interferents masking trace levels of the target analytes, the effects of dirty water (suspended solids) on sensor performance, integration of the SH-SAW devices onto a single piezoelectric substrate for monolithic array, effective delivery of liquid samples to the sensor array in field-ready systems, device drive electronics for optimal power consumption and performance, and general field-application system packaging. Should success be achieved under this effort, continued funding from a customer agency will be sought to address the remaining research & develop issues. Transitional efforts and commercialization planning will lever against past and existing sensor projects at Sandia. Several companies have maintained a continued surveillance of the Sandia Microsensor R&D efforts in hope of capitalizing on new developments.

PROJECT SUMMARY

PROJECT TITLE & ID: Detection and Measurement of Explosives in Groundwater Using In Situ Electrochemical Sensors *(SEED project)*; CU-1220

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Khris Olsen; Pacific Northwest National Laboratory – Richland, WA

FY 2001 FUNDS: $100K

DESCRIPTION: This research project intends to further the development of in situ sensors for the measurement of energetic materials dissolved in groundwater. The proposed research will evaluate the scientific feasibility of applying in situ monitoring technology for measuring TNT, HMX, Tetryl, RDX, and nitrocellulose in groundwater. The objective of the proposed research is to develop in situ sensors capable of replacing conventional methods (sample collection and analysis) for measuring concentrations of TNT, RDX, HMX, Tetryl, and nitrocellulose in groundwater at 20-50 ppb levels with long-term stability (years). This approach may significantly reduce the cost of long-term monitoring. This approach can be used in existing groundwater monitoring wells and may be compatible for installation in explosive contaminated groundwater using direct push technology such as a cone penetrometer system.

BENEFIT: The use of in situ sensors to measure groundwater constituents has significant technical benefits over the standard approach of sampling and analyzing groundwater. For example, measurements taken in situ leave little opportunity for the parameter values to change, as is the case for a sample removed from the aquifer. With traditional sampling and analysis, the sample must be treated carefully after collection to prevent erroneous results. Precautions such as filtering the sample to remove particulates, acidification and cooling of the sample to prevent unwanted chemical changes in the sample are all necessary after a sample has been removed from the natural system. All of these precautions are unnecessary when analyzing the groundwater in situ with downhole sensors. Normally, a sampling program is conducted on a quarterly basis or even monthly in extreme cases. As a result, it is assumed that natural changes in the groundwater occur on a timeframe longer than the sampling frequency. Using sensors, the best sampling frequency can be determined and implemented at no additional cost. The frequency of the sensor measurement is limited only by the time required for a measurement to stabilize. In addition, the sensor measurement frequency can be easily changed on a moment’s notice from the office, enabling the investigator to tailor the measurement cycle to the speed at which the parameter in question is changing. In this way, the sensors allow the investigator to better understand the dynamics of the system and, in turn, better understand the cause for changes and ultimately what mitigating effects are necessary.

The use of in situ sensors to measure important groundwater properties has significant cost saving benefits over the standard approach of sampling and analysis of groundwater. For example, standard sampling requires preparation before each sampling event in which the equipment, pH meter, conductivity meter, thermometer, filtering apparatus, disposable bailers, ice chest and ice, protective clothing, and sample bottles with preservatives and chain-of-custody paperwork must be prepared. Installation costs are required for an in situ sensor system and some minor costs are incurred for maintenance. Once the remote system is operating, the only costs incurred are for data collection from a computer data logging system. Because of the initial capital cost of the sensors, the in situ system would be more costly than standard sampling for a two to three year period, after which, the lower annual costs of the sensors would result in significant long term cost saving.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: Transition of this technology is directly related to the potential significant cost-savings associated with the use of in situ sensors. A significant portion of DoD's restoration budget goes for long-term monitoring costs. Most of the cost is associated with the collection of samples, disposal of purge water, and subsequent sample analysis. This cost will only continue to increase as more sites are added to the cleanup list. In situ sensors offer an alternative to routine sampling and analysis and can result in significant long term cost savings to military installation in and outside the U.S.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Ecological Toxicity and Biomagnification Data for Explosives Contaminants in Soil; CU-1221

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Roman Kuperman; Geo-Centers, Inc. – Aberdeen Proving Ground, MD

FY 2000 FUNDS: $365K

DESCRIPTION: The goal of the proposed research is to determine both the toxicity and the potential for biomagnification of explosives-related soil contaminants, including cyclotrimethylenetrinitramine (RDX), octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX), 2,4-dinitrotoluene (2,4-DNT), 2,6-dinitrotoluene (2,6-DNT) and 1,3,5-trinitrobenzene (TNB) in soil invertebrates and plants. Exposure concentrations will be measured as total chemical concentrations and as the labile portion that is presumed to be bioavailable. Both these chemical measures will be correlated with toxicity endpoints (e.g., growth and reproduction) and biomagnification, with the ultimate goal of developing ecotoxicological parameters for these chemicals based on ecologically relevant soil biota in soils with high bioavailability characteristics.

The goals of this research will be achieved by addressing the following technical objectives: (1) Quantifying the toxicity of RDX, HMX, 2,4-DNT, 2,6-DNT and TNB to soil invertebrates and plants in soils with high bioavailability characteristics (low pH and low organic matter content); (2) Measuring the exposure concentration of these chemicals in soil by different methods to determine if techniques perceived to measure the bioavailable fraction of chemicals in soil are better correlated with biomagnification and toxicity than total chemical measures; (3) Examining the effect of a simulated aging/weathering process on chemical toxicity and biomagnification potential; and (4) Developing ecological soil screening levels (Eco-SSLs) for RDX, HMX, 2,4-DNT, 2,6-DNT and TNB for soil invertebrates and plants based upon concentration-response relationships established during these studies and relating soil physical/chemical properties to the bioavailability and biomagnification potential of these chemicals.

BENEFIT: The proposed research will benefit SERDP by developing ecological soil screening level (Eco-SSL) values and determining bioaccumulation potential for explosives, including RDX, HMX, 2,4-DNT, 2,6-DNT and TNB. These data will be derived from toxicity bioassays with soil invertebrates and plants, based on concentration-response relationships using linear and/or nonlinear regression models. The Eco-SSL benchmarks will be used for the screening of contaminated DoD, DOE, and EPA sites. Scientifically-based Eco-SSLs will identify contaminant levels in soil that present an acceptable ecological risk and can potentially reduce the number of sites requiring clean-up. Screening out potentially contaminated sites early in the ecological risk assessment process can generate a significant cost saving.

ACCOMPLISHMENTS: This is a FY 2000 New Start.

TRANSITION: Both principle investigators are involved with the U.S. EPA effort developing the Ecological Soil Screening Levels (Eco-SSLs) and could therefore provide a direct conduit for the application of data generated during this research in the development of Eco-SSLs. In turn, Eco-SSLs generated with data provided from the proposed work could be used in the screening of soil contamination at DoD sites.

PROJECT SUMMARY

PROJECT TITLE & ID: Toxicological Impact of Ammonium Perchlorate on Fish; CU-1222

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Shane Snyder; Southern Nevada Water Authority – Boulder City, NV

FY 2000 FUNDS: $284K

DESCRIPTION: The research proposed here will determine the potential for effects of perchlorate on common carp reproductive system and thyroid activity by conducting both controlled laboratory exposures and field studies in Lake Mead. Laboratory exposures will be conducted by holding fish under controlled conditions and exposing them to different levels of perchlorate. Exposure concentrations of perchlorate will range from zero (controls) to 1000 µg/L or greater in order to bracket environmentally relevant concentrations. In order to make assessments of reproductive status and thyroid activity in relation to general health, parameters such as sex steroid levels and ratios, thyroid hormone levels, gonadal development and histopathology, gonadosomatic index, thyroid follicle histology, and animal length and weight will be determined. Effects will be compared to perchlorate dose in order to estimate the level of perchlorate that will induce significant changes in the reproductive or thyroid status of the fish. Field studies at Lake Mead will involve the capture of fish from various locations. At these locations, water samples will be collected simultaneously for perchlorate analysis. Furthermore, water quality parameters such as temperature, pH, conductivity, turbidity, dissolved oxygen, ammonia, nitrate, nitrite, and phosphorus will be monitored at each sampling site. Comparisons will be made between observed effects in fish exposed to perchlorate in the laboratory studies and effects observed in wild fish from Lake Mead. Since no standard methods are available for the analysis of fish tissues for perchlorate, attempts will be made develop a suitable method. Additional fish will be captured from Lake Mead to determine if perchlorate has accumulated in the tissues of wild fish.

BENEFIT: This research program will provide the scientific community with a greater understanding of the toxicological impact of perchlorate to fish. Further, this research will determine concentration/effect relationships both from controlled laboratory studies and from real field exposure. If the levels of perchlorate investigated do induce measurable effects, these studies will provide agencies a greater understanding of what levels of perchlorate cause such effects.

ACCOMPLISHMENTS: This is a FY 2000 New Start.

TRANSITION: If it is determined that perchlorate can bioaccumulate in fish or alter reproductive or thyroid activity in fish, this study will serve as a starting point for further work needed to characterize the level of risk that perchlorate poses to the environment. These data will be published in peer-reviewed scientific journals which will not only share the knowledge gained through these studies with the scientific community, but also subject the data to review by knowledgeable scientists.

PROJECT SUMMARY

PROJECT TITLE & ID: Ecological Risk Assessment of Ammonium Perchlorate on Fish, Amphibians, and Small Mammals; CU-1223

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Ronald Kendall; Texas Tech University – Lubbock, TX

FY 2000 FUNDS: $1367K

DESCRIPTION: The technical objective of the proposed research is to fully assess the environmental impacts of perchlorate contamination using innovative risk assessment methodologies to accurately describe and quantify risks associated with ecological assemblages exposed to perchlorate. The project intends to transition considerable amounts of data and information from previous laboratory assessments of perchlorate toxicity into a comprehensive field assessment at the Longhorn Army Ammunition Plant (LHAAP) near Karnack, Texas. The project team has performed a rigorous site assessment at this facility and have identified numerous areas with elevated perchlorate contamination resulting from historical Department of Defense (DoD) activities.

The project will initiate (and in some cases continue) laboratory and field investigations to further elucidate ecological risks associated with perchlorate contamination. Indigenous plant, fish, amphibian, and mammalian species will be examined as potentially sensitive receptors and vectors of perchlorate movement through food webs. The project will capitalize on new analytical methods developed during previous research for the detection of perchlorate in biological matrices to establish tissue-level exposure indices among the various organisms that are critical for realistic assessment of ecological risks.

Additionally, perchlorate exposures will be linked with appropriate toxicological endpoints developed in previous laboratory studies including thyroid hormone and reproductive steroid concentrations, as well as population endpoints such as reproductive success, survival and development. Laboratory data generated over the past two years, and data generated from the proposed field studies will be incorporated into models of contaminant movement and physiological-based pharmacokinetic (PBPK) models to better describe the ecological risks associated with perchlorate contamination.

BENEFIT: Through this research, data vital to the development of regulatory cleanup standards for perchlorate-contaminated sites will be generated. Risk-based approaches will be applied to the site assessment of LHAAP, Karnack, Texas consistent with accepted risk management paradigms and will support the use of the best and most current science to reduce the uncertainty in estimating risk of toxic substances to the environment.

ACCOMPLISHMENTS: This is a FY 2000 New Start.

TRANSITION: Information gained from the proposed research will be transitioned to agencies within the DoD, the Interagency Perchlorate Steering Committee (IPSC), the U.S. EPA, other federal and state agencies and the general scientific community through reports and peer-reviewed publications. The products of this research will provide a framework of risk assessment methods and criteria necessary to define acceptable concentrations of perchlorate within ecological systems. These data will be useful not only in the characterization of LHAAP but will also be applicable for use in the assessment of other perchlorate-contaminated sites operated by DoD and sites potentially affecting valuable water supplies.

APPENDIX B
Compliance Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: Improved Incorporation of Health and Safety to Facilitate Accelerated Implementation of Innovative Environmental Technologies; CP-819

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Raymond Lovett; National Environmental Education & Training Center – Indiana, PA

FY 2000 COMPLETED PROJECT

DESCRIPTION: New environmental technologies are often designed for efficacy with little consideration given to the safety of the technology to an operator, a maintenance worker or the community. As a result, significant time and energy is spent on re-engineering technologies to address health and safety issues. This project sought to (1) create, as an effective, deliverable tool for technology developers, a knowledge-based prototype system, known as TEXPERT, to evaluate and incorporate health and safety concerns into the design of environmental technologies, and (2) improve health and safety information and its dissemination during technology deployment.

TEXPERT provides new technology developers with access to an "occupationally and environmentally focused total system design assessment tool" through an Internet site (http://jill.computercomp.com/texpert/) that is linked to databases and software tools (using Environmental Protection Agency formats) on health and safety associated with known technologies, risk assessment, preliminary hazard recognition and analysis, fault-tree analysis, and job safety analysis.

BENEFIT: The tools and data developed under this project, when coupled with existing "engineering design and management tools" will assist designers and technology implementors in evaluating and assessing health and safety issues in a focused, systematic way. It will lead to a consideration of worker and environmental safety and health implications associated with field (or production) use of innovative technology, and minimize the occurrence of health and safety concerns before and during end-user implementation.

ACCOMPLISHMENTS: The National Environmental Education and Training Center, Inc. has begun the evaluation of a field environmental technology test. A draft CD of training methods has been produced which is the basis for the design of the final product. The task to evaluate ship scrapping has begun and a memorandum of agreement (MOA) has been signed with the U.S. Navy to begin acquisition of data. Baseline descriptions of existing scrapping processes were developed at the Philadelphia Naval Yard and at the Puget Sound Naval Station.

TRANSITION: Transition is an ongoing part of this project and will consist of full implementation of an expert system made available on the Internet or on diskette, demonstration at two technology development sites, and integration with a similar DOE program. Implementation of an outreach program via the Internet is also planned.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Non-Thermal Plasma Reactor Technology for Control of Atmospheric Emissions; CP-1038

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Louis Rosocha; Los Alamos National Laboratory – Los Alamos, NM

FY 2000 COMPLETED PROJECT

DESCRIPTION: The overall objective of this project was to evaluate and develop new non-thermal plasma (NTP) reactor technologies for Department of Defense (DoD) air emissions control applications while providing a basis for selecting the most appropriate NTP technology. This was accomplished by evaluating the performance of prototype and pilot-scale NTP reactors (i.e., corona, dielectric barrier, and electron beam) for Nitrogen Oxides (NOx) and Hazardous Air Pollutant (HAP) abatement and specialized Volatile Organic Compound (VOC) control. The development of an efficient, reductive-model NOx processor was a key goal.

BENEFIT: All organizations within the DoD, the Department of Energy (DOE), and industry affected by the need to control emissions of NOx, HAPs, and VOCs will benefit from the development of a flexible technology for emissions control and a basis of selecting the most appropriate technology for specific needs. With the successful development and implementation of NTP technology, present and planned DoD activities can proceed without deleterious environmental impacts or major compliance-issues and cost escalations. Particular technical results from this project include an increase in the efficiency of electric-discharge NTP (by control of discharge physics and plasma chemistry) and the potential for development of low back-pressure, filterless, scrubberless NOx control equipment using reductive mode processing, effected by improved electrical driver technology. Also, other VOC-abatement technologies are not yet fully proven, therefore, NTP can be a promising back-up for these technologies in some cases.

ACCOMPLISHMENTS: The main corona radical shower (CRS) reactor and its enclosures was fabricated with acquisition and installation of reactor power supplies, the electrostatic filter elements, catalytic converters, and the variable-speed fan used to draw exhaust gas through the system. A small-pilot-scale field demonstration on NOx removal for a test cell at Tinker Air Force Base showed promising results for some operating conditions. The CRS NTP reactor used a large collection of fine nozzles, connected to a source of high voltage, to inject a mixture of air and dilute ammonia (NH_3)/nitrogen (N_2) into the portion of the test cell exhaust-gas stream sampled by the plasma reactor. The combination of non-thermal plasma formed at the nozzle tips using the injection gas produced active species for de-NOx (e.g., O-atoms, N-atoms, NH radicals, etc.). In the field tests, 70-100% de-NO was achieved because the CRS reactor was operated primarily under oxidizing conditions. For some cases (main gas flow rate < 80 Nm^3/h), the combination of radical chemistry, reaction with NH_3, and reactions in the catalytic bank achieved 65-80% total de-NOx.

TRANSITION: The transition plan for this project involved coordination with users and with industry, and full-scale implementation within DoD/DOE. User coordination includes: Air Force NOx abatement projects, JETC and diesel engine NOx abatement, VOC control at Tinker Air Force Base, emission control for the "Burn Box" at the Army's Aberdeen Test Center, and multi-agency interfacing via Los Alamos Environmental Management (EM) and DoD Program Managers. Industry coordination included existing technology-commercialization Cooperative Research and Development Agreements (CRADAs) with the Electric Power Research Institute (EPRI) and High Mesa Technologies (HMT), potential future CRADAs with HMT and Environmental Elements, and Los Alamos Industrial Partnership Office promotion of industrial interaction.

PROJECT SUMMARY

PROJECT TITLE & ID: Development and Integration of Laser-Based Sensors for VOC/NOx and Metals Emissions Monitoring; CP-1060

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Scott Bisson; Sandia National Laboratory – Livermore, CA, and Dr. Meng-Dawn Cheng, Oak Ridge National Laboratory – Oak Ridge, TN

FY 2000 COMPLETED PROJECT

DESCRIPTION: The objective of this project was to develop a combined laser-based system for monitoring volatile organic compounds (VOC), nitrogen oxides (NOx), and metals for compliance with the Clean Air Act Amendments of 1990. For gaseous pollutants, an infrared (IR) spectrometer based on the new, periodically-poled lithium niobate (PPLN) laser technology was used. For metals emissions monitoring, laser induced breakdown spectroscopy (LIBS) was employed.

For development of the IR Spectrometer, the tunability, spectral bandwidth, and oscillation threshold of the PPLN source was characterized. Given the wide range of species to be detected and the fact that the absorption spectra span the infrared, broad tunability is essential. The detection sensitivity was also optimized through the use of acoustically resonant cells. For development of the portable LIBS (PLIBS), currently available solid-state diode lasers were identified and evaluated for long-term operation. The feasibility of using a solid-state laser for plasma ignition and spark generation was investigated. This reduces the physical dimension and weight of the PLIBS system substantially. Other compact lasers such as a diode-pumped Nd:YAG laser were also evaluated.

BENEFIT: This technology will allow, for the first time, near real-time, in-situ analysis for monitoring a wide range of chemical species (metals and gases) with higher sensitivity than previously achievable. There are also potential applications in process control and atmospheric chemistry research. Moreover, the compact size of this new system is attractive, making a portable system a possibility, and its cost is anticipated to be competitive with many conventional, laboratory analytical services.

ACCOMPLISHMENTS: Field tests of the photoacoustic spectrometer were recently completed at a paint shop in a particularly challenging measurement environment, as many types of VOCs were emitted and a water curtain was used to scrub the effluents before release to the atmosphere. With the combined broad and fine tuning capability of the PPLN based laser, VOCs can be both detected and speciated in the presence of high water vapor concentrations. In a field test of the PLIBS system at an engine test cell, emissions were spiked with selected metals inside a dilution tunnel. Operating conditions were varied to simulate actual emissions that are known to be highly transient and complex with respect to chemical composition. The compact portable system yielded on-line analysis data with great precision in a small test cell under harsh environmental conditions. Further, no loss of reactive species, such as mercury(II), was experienced.

TRANSITION: Two important collaborations have been established. The first involves work with a group (leaders in gas-phase photoacoustic spectroscopy for environmental and biological applications) from the Catholic University of Nijmegen in the Netherlands. The second involves Coherent Inc., a laser company that is developing a laboratory PPLN laser. These collaborations provide a potential technology transfer path for a fieldable photoacoustic system.

PROJECT SUMMARY

PROJECT TITLE & ID: Detect and Identify Multiple Hazardous Air Pollutants (HAP) at Extended Distances; CP-1061

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Antonio Ting; Naval Research Laboratory – Washington, DC

FY 2000 COMPLETED PROJECT

DESCRIPTION: The objective of this project was to develop a new class of sources for active remote sensing of hazardous air pollutants (HAP) using ultra broadband (UB) radiation, and techniques for their detection and identification. UB radiation can provide the necessary illumination required for active remote sensing to allow real-time ranging and identification of HAPs at extended distances. The mechanism for the generation of UB radiation is based on self-phase modulation of picosecond laser pulses in a nonlinear optical medium. Continuous UB radiation can be generated with extremely high efficiency and high average power by beating two laser beams with slightly different frequencies. The bandwidth of the radiation can extend from the optical to the Infrared (IR) regime. The source size of the UB radiation is extremely small, which allows for beaming the radiation over extended distances of several kilometers.

The generation of UB radiation in various nonlinear materials was evaluated using existing laser facilities at the Naval Research Laboratory (NRL). Lasers with optical and near-IR wavelengths were used to generate UB. The conversion efficiency and bandwidth were optimized by selecting the appropriate nonlinear medium. The quality of the UB radiation beam was measured and its propagation in air characterized. The methodology and diagnostics necessary to evaluate the UB spectrum were based on hyperspectral imaging techniques that are being developed at NRL. Proof-of-principle experiments on active remote sensing were performed, and data reduction techniques for analyzing complex spectral signatures were studied.

BENEFIT: The application of UB radiation sources to remote sensing can lead to the identification, ranging, and detection of HAPs at extended distances through simultaneous spectral response from various HAPs. It will allow the tracking of nitrogen oxides (NOx), chlorine oxides (ClOx), and sulfur oxides (SOx). UB radiation is also especially valuable during night-time monitoring when sunlight is not available for conventional remote sensing methods. A system of active remote sensing using UB radiation will benefit efforts for continuous, real-time identification of HAPs that are of concern to the Department of Defense (DoD).

ACCOMPLISHMENTS: A laboratory scale prototype for active remote sensing of HAP using UB radiation was constructed. This included two spectrometers and two linear detectors and the novel collection of return signals. The automated operation and data collection system was implemented. Experiments were performed using various concentrations of sample HAPs and the preliminary data using the Kalman filter algorithm technique was analyzed. A successful analysis of the experimental setup was completed. The project also finished construction of 1.32 um Nd:YAG laser and performed lasing of the 1.32 um laser. Preliminary UB radiation from 1.32 um laser was successfully generated.

TRANSITION: The Transition Plan includes further development including testing of the device in a field environment. Additional transition could occur in Small Business Innovation Research (SBIR) Phase I and II leading to Cooperative Research and Development Agreement (CRADA) Programs. The signal processing algorithm for the identification of HAPs with UB radiation was presented at an International Conference on Signal and Image Processing.

PROJECT SUMMARY

PROJECT TITLE & ID: Plasma-Assisted Catalytic Reduction of NOx; CP-1077

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Joseph Wander; Air Force Research Laboratory – Tyndall Air Force Base, FL

FY 2000 COMPLETED PROJECT

DESCRIPTION: The objective of this project was further develop and optimize selective catalytic reduction (SCR) technology by using a non-thermal plasma (NTP) to assist with the catalytic destruction of nitrogen-species contained in gaseous emissions. It extended bench-level observations of the cold-plasma-induced catalyzed chemistry of propene in simulated combustion-exhaust gases to include mixtures of fuel constituents common to JP-8 in actual combustion exhaust. In the SCR process, the destruction of partially oxidized nitrogen-based contaminants found in combustion-exhaust emissions proceeds by oxidation of nitrogen-species to NO_2 which are subsequently reduced to N_2 by hydrocarbons (HC) such as found in fuels. By choosing oxidation-catalyst components that pre-convert NO fully to NO_2 and mechanically mix them with reduction-catalysts, catalysts previously regarded as inactive for nitrogen oxide (NOx) reduction have been shown to become efficient. Bench-scale studies on a simulated exhaust gas using propene as the reductant have accomplished a very efficient conversion of the mixture to N_2, CO_2, and water.

The main technical challenge was maintaining high efficiency for NOx reduction when flow-rates were increased to pilot-scale (50 cfm), and when diesel fuel (and kerosene-like liquid hydrocarbons) was used as the reductant.

BENEFIT: Augmentation of the SCR process by NTP increases the efficiency of removal of NOx and decreases the consumption of power and of added reducing agent. More importantly, it permits use of engine fuel HCs as the reducing agent instead of requiring a separate supply of ammonia or some other nonstandard hazardous material.

ACCOMPLISHMENTS: A full-scale engineering prototype SCR/NTP system to evaluate the treatment of exhaust from a 6-L diesel engine has been designed and is being assembled in preparation for long-term testing. Projections of the cost/benefit of a full-scale control process are favorable. After initial benchtop studies using propene as the reductant, bench-and pilot-scale studies on splits of diesel exhaust using diesel fuel as the reductant have achieved less-efficient but still practical conversion of NOx into N_2, carbon dioxide (CO_2), and water. The extent of NOx conversion appears to be independent of scale, and the process does not appear to be affected by fuel sulfur. A tentative design for a field-ready unit has been prepared.

TRANSITION: The technology is ready for transition to an Environmental Security Technology Certification Program (ESTCP)-type demonstration and evaluation of a scaled-up prototype within two years. A commercial partner, Cummins Engine Co., is committed to deploying this technology as soon as it is technologically and economically viable.

PROJECT SUMMARY

PROJECT TITLE & ID: Hypergolic Non-Detonative Neutralization in Production and Demilitarization; CP-1079

PRINCIPAL INVESTIGATOR & ORGANIZATION: Ms. Pamela Walker; Sandia National Laboratory – Albuquerque, NM

FY 2000 COMPLETED PROJECT

DESCRIPTION: The objective of this project was to develop an innovative, alternative technology to replace open burn/open detonation (OB/OD) operations for the destruction and disposal of obsolete, excessive, and off-specification energetic materials. The focus of this project was to develop effective reagents and to understand the underlying chemistry for reacting the energetic materials with a hypergolic chemical, which neutralizes the energetic materials and precludes a detonation. The proposed approach used organic amines, metal alkyls or amine-metal alkyl adducts to neutralize explosives. These have been shown to react hypergolically with Trinitrotoluene (TNT), Composition B, and RDX.

The chemistry related to the interaction of organic amines and metal alkyls with explosives is poorly understood and one objective of this program was to further elucidate the reaction mechanisms. Two approaches were being used for the pre-treatment of explosives: (1) relatively low temperature, controlled exothermic reactions in a liquid-phase environment, and (2) solid-state, controlled hypergolic reactions. Overall these approaches have great potential in the pre-treatment of explosives to produce a non-detonable product for reuse or final treatment in a steam reforming reactor. The project focused on the identification of the reaction products, their toxicity and potential reuse. Thin layer chromatography, high pressure liquid chromatography, infrared, nuclear magnetic resonance, and mass spectroscopy were employed. The products were purified to facilitate their identification, and reactions with simpler amines such as cyclohexylamine and ethylenediamine were also conducted to eliminate the potential for polymerization which complicates product identification.

BENEFIT: This project provides DoD and DOE with an alternative method for safe and effective disposal of energetic materials. These new methods are based on chemical breakdown of the energetic materials without detonation and are expected to exhibit high throughput, cost effectiveness, and possibilities for reuse/reapplication of the byproducts.

ACCOMPLISHMENTS: When employed as hypergolic reactants, ethanolamine and diethylenetriamine each exhibited controlled exothermic reactions with trinitrotoluene (TNT) at room temperature in a variety of solvents and in the solid state. Diethylenetriamine also reacted with hexahydro-trinitro-triazine (RDX) exothermically in the temperature range of 90-140°C, but in a safe and controlled manner. The energy release from the reaction with TNT can be used to initiate the reaction with RDX and enable deactivation of the explosive material known as Composition B (which is composed of 40 percent TNT, 59 percent RDX, and 1 percent wax). Detonation never has occurred in numerous field tests even though the explosive (up to 100 g) was confined during the decomposition process. Differential scanning calorimetry has been used to show that TNT is destroyed and an intermediate compound is formed during these hypergolic reactions. The remediation and sustainment of firing ranges can be accomplished by using “jeffamine”, a trifunctional primary amine, to clean the metal shrapnel from detonated conventional weapons. Several pieces of 105 mm shells (TNT loaded) which had seen low-order detonation were collected from Sandia's remote firing range. A 7 minute dunk of the scraps in hot jeffamine, followed by a water rinse, left just nanograms of explosive on the surface, as detected by high performance liquid chromatography. Lab-scale tests were completed in which actual chunks of Comp B acquired from McAlester Army Ammunition Plant were reacted with hot “jeffamine”. These were done to assure that large pieces of explosive would not detonate. Previously, lab-scale tests were done using finely divided explosive powders. None of the "chunk" tests resulted in detonation. This indicates that no pre-grinding of explosives is needed before the chunks are introduced into the scale-up reaction vessel.

TRANSITION: The technology developed under this project will be made available to users within DoD and DOE, including partners for prior collaborative efforts. Conventional chemical processing equipment is adequate for full scale implementation of this technology.

PROJECT SUMMARY

PROJECT TITLE & ID: Optimization of an Innovative Biofiltration System as a VOC Control Technology for Aircraft Painting Facilities; CP-1104

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kerry Kinney; University of Texas – Austin, TX

FY 2001 FUNDS: $95K

DESCRIPTION: Until alternative coating materials and depainting operations become available, treatment of fugitive volatile organic compound (VOC) contaminant releases during application or removal of coatings is necessary to maintain compliance with the Clean Air Act Amendments of 1990. Currently available VOC emission control technologies are costly at the high volumetric flow rates and low contaminant concentrations associated with the ventilation of aircraft hangars. This project will develop an innovative, high flow-rate biofiltration method for treating VOC-laden air emissions. Biofiltration of painting off-gas streams currently is limited, not because of insurmountable technical problems but simply because current systems have not been designed to handle the operating conditions typical at these facilities. Innovative design features and biofilter configurations are being investigated, tested, and applied to an actual Air Force paint spray booth.

The following innovative design features are being investigated for their ability to improve biofilter performance for paint spray booth applications: (1) a recirculating inoculation method to shorten the bioreactor start-up period; (2) directionally-switching operation to improve biomass distribution and prevent clogging; (3) slip-stream feed to maintain high biomass activities during paint spray booth shutdown periods; and (4) an aerosol nutrient delivery system to efficiently deliver nutrients and moisture to the biofilm. Since bioreactor performance is strongly influenced by the contaminants being treated, the effectiveness of each design modification will be determined under single (e.g., ethyl acetate) as well as multiple [e.g., methyl ethyl ketone (MEK), methyl isobutyl ketone (MIBK), toluene] contaminant conditions representative of paint spray emissions. Other risks are whether stable and effective, long-term operation can be achieved while operating in a directionally-switching mode and using an aerosol nutrient/moisture delivery system.

BENEFIT: The project will provide a stable biofiltration system for paint spray booth applications that operate intermittently and emit varying quantities of VOCs. Typical biofilter problems such as long acclimation times, slow response to load changes, and biomass clogging will be overcome. The innovative biofiltration process developed by this project will, therefore, be suitable for venting of aircraft hangars during application or removal of coatings. It has the added advantages of operating at ambient temperatures and minimizing the generation of secondary wastes.

ACCOMPLISHMENTS: An experimental plan, test system, and experimental protocols for the project were developed and start-up experiments have been completed. The research team has isolated and developed bacterial cultures that degrade toluene, ethyl acetate, and MEK the major contaminants found in paint spray emissions.

For the fungal bioreactor portion of the study, the ability of the black yeast *Exophiala lecanii-corni* to degrade paint VOCs was assessed. The fungus was found to be able to use toluene, ethyl benzene, methyl propyl ketone, n-butyl acetate, and ethyl ethoxypropionate as sole sources of carbon and energy; however, *E. lecanii-corni* was unable to degrade either xylene or benzene. When a mixture of paint chemicals were added to cultures of E. lecanii-corni, the fungus again degraded all of the chemicals except xylene or benzene. Preliminary studies indicate that *E. lecanii-corni* would be a feasible organism to use for paint spray booth applications due to its ability to degrade a wide range of paint VOCs, even under harsh environmental conditions.

In concert with an EPA-funded project, the project has also begun developing a model to predict the long-term performance of biofilters. The new model has been formulated to account for the loss of active biomass with time in a bioreactor and can be used to simulate much longer periods of operation (e.g., up to 4 months or longer). However, the model was developed to simulate the degradation of only one model pollutant at a time (e.g., toluene) and does not include mixture effects.

TRANSITION: The primary users of the biofiltration technology will be DoD paint spray booth facilities; however, the technology also will be widely applicable to the private sector. Research results are being published in forums that reach a large audience of professionals in air pollution control including the Annual Meeting of Air and Waste Management Association. A web site also will be dedicated to the proposed research and will include brief statements related to research objectives and interim results.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of Particulate Emission: Size Characterization and Chemical Speciation; CP-1106

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Adel Sarofim; University of Utah – Salt Lake City, UT

FY 2001 FUNDS: $689K

DESCRIPTION: The objectives of this project are to develop advanced methods for the measurement of the size distribution and composition of particulate matter (PM) emitted from mobile and stationary sources and provide the Department of Defense (DoD) with the tools needed to characterize and control the emissions from DoD facilities. The feasibility of using advanced analytical measurements to characterize the chemical composition and size of particulate emissions from a diverse range of sources operated by the DoD will be determined. The data obtained during the evaluation of the instruments will provide a measure of the relative importance of different DoD sources and will be useful for guiding strategies for controlling the emissions from DoD facilities. The cost effectiveness of different measurement methods will be assessed and recommendations made for the best protocols for measurement of fine particle emissions.

Two innovative techniques for rapid measurement of fine particles will be used in combination with a dilution sampler. The first is an aerosol time of flight mass spectrometer (ATOFMS) that measures the size and composition of individual articles. The second is a photoelectric aerosol sampler (PAS) which, in combination with a photoacoustic elemental detector (PED) for carbon, provides rapid measurement of the polycyclic aromatic hydrocarbon (PAH)-laden carbonaceous particles which dominate the emissions from combustion sources. The objective is to apply these devices in parallel with more conventional measurement techniques to establish their validity for characterizing the particle emissions from DoD sources. Multiorifice impactors (MOI) combined with chemical analysis will be used to obtain chemical characterization sufficiently detailed to close material balances on the emissions. Optical particle counters (OPC) and differential mobility analyzers (DMA) will be used to obtain detailed size distributions in order to calibrate the ATOFMS and PAS.

BENEFIT: The project will provide DoD with rapid measurement procedures for organic and inorganic particulate emissions at greatly reduced cost per analysis, as well as detailed chemical compositions of major particulate source categories by size. Assessments will be provided of the relative cost of alternative measurement strategies, ease of use, potential use for feedback control, reliability, and speed.

ACCOMPLISHMENTS: The value of the ATOFMS for providing diagnostic information involving diesel operations has been demonstrated. A model has been developed to assess the impact of dilution sampling on particle size distribution. The ATOFMS has provided important data on the different classes of compounds emitted by diesel and spark ignition engines as well as coal-fired facilities. Size distributions and chemical compositions have been obtained on diesel emissions. The PAS has shown potential for measuring engine emissions under operating conditions from off-runway measurements. The photoacoustic detector has been applied successfully to monitor the elemental carbon emission from aircraft ground equipment. PAH distribution between vapor and particles and downstream of a filter have been determined. Three major activities were completed during FY 2000: (1) chemical analysis of coal combustion emissions data, (2) implementation of ambient and source sampling at Hill Air Force Base, and (3) construction of the ultrafine inlet for the ATOFMS. The emission profiles were also used to generate calibration curves for the ATOFMS.

The team completed the chemical measurements of the filter samples of particulate matter emissions collected in parallel with the ATOFMS data. These measurements include fine particle mass, fine particle elemental and organic carbon, fine particle trace metals, water-soluble ions, and organic compound speciation. In addition, size resolved chemical composition of the particulate matter emissions were obtained that include fine particle mass, fine particle elemental and organic carbon, fine particle trace metals, and water-soluble ions.

Qualitative chemical analyses of the ATOFMS data for the dynamometer test are complete, detailing both diesel and gasoline vehicular particulate emissions. Qualitative analyses of the coal combustion particulate emission tests are nearly complete, and certain findings from the biomass emission tests have been reported with others currently being investigated.

Instrumental enhancements of the ATOFMS are currently in progress. Work is underway to optimize a recently constructed ultrafine particle (<100 nm) sampling interface to the ATOFMS. Computational studies of the effects of dilution rate on the measured size distribution and concentration of submicron aerosols in internal combustion engine exhaust continued. Topics investigated include: the half-life of nanosize particles in filtered and ambient air, the effect of nanoparticles below the instrument detection limit (typically 6-10 nm) on observed coagulation of ultrafine aerosols, transformation of hypothetical source aerosols when diluted using various dilution methods described in the literature, and the relative importance of coagulation, surface growth, and nucleation on the measured size distribution. Computational fluid mechanics (CFD) - based simulations have been conducted on the mixing of the exhaust from a diesel truck in a cross wind to obtain realistic time-concentration histories to compare free, ambient dilution with laboratory sample dilution procedures.

TRANSITIO N: At the end of the source test program, the techniques used in the advanced source test system will be evaluated in terms of ease of use, time of sampling to obtain data, time to analyze data, and capital and operating costs. Negotiations are in progress to produce a commercial version of the ATOFMS. The current project will have developed the calibrations necessary for producing quantitative emission measurements on DoD sources as well as provided a measure of the cost effectiveness of using this technology. During the course of the project, personnel from Hill Air Force Base and the Air Force Research Laboratory will evaluate the ease of transfer of the instruments to the field.

PROJECT SUMMARY

PROJECT TITLE & ID: Electrochemical Advanced Oxidation Process for Shipboard Final Purification of Filtered Black Water, Gray Water, and Bilge Water; CP-1107

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Oleh Weres; Sonoma Research Company – Napa, CA

FY 2000 COMPLETED PROJECT

DESCRIPTION: The overall objective of this project was to advance development of an electrochemical Advanced Oxidation Process (AOP) which will be used as a final polishing step following membrane filtration of shipboard wastewater. To comply with International Maritime Organizations Marine Pollution Convention (MARPOL) Annex V and other environmental regulations, U.S. Navy vessels require compact, energy efficient water purification technology that will allow most of the wastewaters produced on board (bilge, gray, black, etc.) to be discharged overboard following purification. Membrane filtration does not achieve the degree of purification required, and a final "polishing" process is needed prior to discharge overboard. The specific objectives of this project included producing AOP electrodes with improved service life and improved performance at low substrate concentrations, developing methods for reprocessing the electrodes, and identifying optimal operating conditions for the AOP.

Existing equipment for producing small test electrodes in the laboratory were upgraded. An apparatus permitting long-term testing of the electrodes was developed, and a correlation of service life vs. current density was determined. Tests were developed to evaluate the kinetics of different oxidation mechanisms for several substrates. X-ray diffraction, scanning electron microscopy, and specialized surface analyses were used to characterize the crystal structure, surface morphology, and surface composition of the electrodes. Fiber made of the alloy Ti-6Al-4V (aerospace titanium) were procured and evaluated for service as an electrode substrate. This alloy is expected to decrease the brittleness of the porous anodes produced, and thereby allow reprocessing of used-up electrodes at a fraction of replacement cost.

BENEFIT: Once the practical feasibility of this technology has been demonstrated, the U.S. Navy will be able to decide which combination of shipboard wastewater treatment technologies to use. In combination with improved membrane filtration technology, electrochemical AOP will allow existing ships to be retrofitted for compliance with MARPOL Annex V and other regulations. Estimated cost savings over 20 years are $1.49 billion (estimate of cost to off-load untreated wastewaters). Electrochemical AOP will find broad military and industrial applications, wherever moderate concentrations of contaminants need to be removed from water at moderate cost.

ACCOMPLISHMENTS: Work on the electrochemical subsystem of the apparatus to measure the electrical properties of the anodes has been completed along with the design and construction of accompanying electronics. The computer program needed to analyze this data has also been written. The complete system will be able to determine current, DC impedance, AC impedance and the capacitance of the anode as a function of anode potential in a single test. Electrode coating methods have been thoroughly reviewed and approximately fifty test electrodes with precisely documented production histories were developed. This substantial inventory of electrodes will allow the investigators to proceed with the application of a second overcoat to increase the effective surface area of the electrode. A provisional patent application, which covers developments since the original patents were filed in 1992, was filed. Cyanide in a sample of wastewater obtained from Keyport, WA was successfully destroyed at pH 10.8 in test cells and the Naval Facilities Engineering Service Center (NFESC) prototype. Additional tests were run with sodium cyanide. The reaction rate was monitored using a cyanide ion-specific electrode and proved to be consistent with

N/OH. The transition from zero order kinetics to first-order kinetics as the reaction proceeded was clearly visible in the data, directly confirming the model of reaction kinetics. A steam chamber, which will be used for the production of full-sized electrodes, was built.

TRANSITION: Interested potential users have been identified, including: the Naval Facilities Engineering Center, the Carderock Naval Surface Warfare Center, Eaton Corporation, and Showa Engineering Co. of Tokyo, Japan. *Chemical Engineering* magazine twice described this technology, eliciting 130 requests for information. The prototype water treatment unit will very likely be carried forward to eventual commercialization.

PROJECT SUMMARY

PROJECT TITLE & ID: Novel Nonporous Fouling-Resistant Composite Nanofiltration Membranes and Membrane Separation Systems for Wastewater Treatment; CP-1108

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Benny Freeman; North Carolina State University – Raleigh, NC

FY 2000 COMPLETED PROJECT

DESCRIPTION: Fouling associated with currently available membranes is the principal problem inhibiting widespread adoption of nanofiltration/ultrafiltration to treat shipboard wastewater to allow the Navy to meet current and future overboard discharge limits. All current nanofiltration/ultrafiltration membranes are finely porous and are subject to surface or internal fouling by particulates, resulting in a dramatic decline in the water flux. The objective of this project was to develop a shipboard wastewater treatment system based on a novel type of fouling-resistant, composite-membrane module. The composite membrane consists of an ultrathin (0.2-0.5 micrometer), nonporous, highly water-permeable, rubbery, block copolymer layer coated on to a conventional, microporous ultrafiltration or nanofiltration membrane for support. This coating layer provides fouling resistance without significantly reducing the water flux.

Three candidate materials have been developed under earlier Office of Naval Research grants. In this project, development of these membranes were completed and a systematic series of new materials was synthesized and characterized. The properties of these new heterophase block copolymer membrane materials were tailored to provide better fouling resistance than conventional membranes while maintaining or improving the flux/selectivity combinations relative to currently available materials. These materials were based on aromatic polyamide hard blocks with either hydrophilic ether groups as the soft, water-permeable block or water-soluble aromatic polyamides as the hydrophilic blocks. This research program characterized the physical, chemical, and morphological structure of these materials as well as their water permeation, rejection, and fouling properties to develop systematic structure/property relations to guide the preparation of a new generation of advanced high performance materials for shipboard wastewater treatment. The best membrane materials were selected for scale-up, first to bench-scale and then to industrial-scale membrane modules for evaluation in a pilot-scale system.

BENEFIT: Novel, low-fouling membranes for graywater and bilgewater treatment would offer longer service life and less frequent cleaning. When housed in high performance modules, these would provide a compact, reliable, economical shipboard wastewater treatment facility to enable the Navy to meet current and anticipated wastewater purification targets. This technology is widely applicable to Navy and civilian ships and to onshore treatment of highly fouling waters.

ACCOMPLISHMENTS: Several classes of polymers were prepared based on block copolymers. Eight 40-inch-wide runs of Pebax 1074 membrane were conducted and the resulting gas permeation measurements showed that the membrane was defect-free. Flux and rejection data showed that Pebax membranes resist oil/water emulsion fouling. Chitosan and chitosan derivatives were prepared, and although the chitin films, based on acetic acid, have higher water uptake than the chitin-like films based on formic acid, the latter films have an advantage over the former with respect to mechanical strength, both when wet or when dry, after one or more cycles of soaking, drying, resoaking, redrying, etc. The chitin samples were found to be brittle after only 1-2 wet/dry cycles whereas the chitin-like formamide films are tough after many wet/dry cycles. The team also prepared a similar polymer having methoxy terminated polyethylene glycol (PEG) pendent amide groups. Water uptake in the previous work was about 288% and in the recent work only about 134%. It would thus appear that one long PEG group may be more effective for water uptake in chitin-like polymers than four shorter PEG groups.

The project team prepared high flux, thin film composite membranes from commercial Pebax polyether-b-polyamide copolymers. Under the Bench-scale Module Development task, the team determined the performance and stability of a module containing Pebax 1074 membrane coated onto a microporous poly(vinylidene fluoride) [PVDF] support. The team completed a 50 day test on the laboratory pilot system for the long-term evaluation of spiral-wound membrane modules for oil/water separation.

TRANSITION: Collaboration will occur with Hydranautics Inc., San Diego, California in the module preparation work in the final phase of the project. Hydranautics is a major producer of membrane water treatment modules in the U.S. and would be a logical commercialization partner to introduce this technology to the water treatment market.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of a Catalyzed Ceramic Filter for Combined $PM_{2.5}$ Removal and VOC and CO Oxidation; CP-1120

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Goldsmith; CeraMem Corporation – Waltham, MA

FY 2001 FUNDS: $288K

DESCRIPTION: The objective of this project is to develop high performance filters applicable to the treatment of a number of Department of Defense (DoD) combustion gas streams. The filters will be highly compact, ceramic-membrane-coated, silicon carbide (SiC) monolith filters, which can be additionally coated with non-selective catalysts to achieve simultaneous removal of particulate matter while oxidizing vapor-phase volatile organic compounds (VOC) and carbon monoxide (CO). The oxidation catalysts can also result in "passive" regeneration of soot to allow extended continuous operation.

The project will be carried out in three phases to develop high performance filters to control pollutant emissions from combustion gas sources: (1) Development and characterization of SiC monolith filters which will be operated in various modes, either for high-efficiency full-particulate-retention, passive catalytic regeneration or backpulse regeneration; (2) Scale-up of filter construction, catalyst impregnation methods, and testing; and (3) Single-filter, slip-stream tests at selected DoD user sites. Three types of filter will be tested. The first is a backpulse-regenerable, compact, ceramic filter capable of reducing particulate concentrations to PM_{25} compliant levels. The second is similar to the first except that an oxidation catalyst will be deposited on and within the pore structure in order to simultaneously remove gaseous pollutants such as VOCs and CO. The third filter type will be similar to the first except that an oxidation catalyst for removal of organic particulate will be deposited on the surface of the membrane coating. This catalyst will passively regenerate the filter by oxidizing the filtered particulates, thereby eliminating the need for backpulsing. After the development of prototype filters, field tests will be conducted to demonstrate the efficacy of removing particulates, VOCs and CO from selected gas streams.

BENEFIT: The DoD and Department of Energy (DOE) need new, cost-effective technologies to comply with the proposed, more stringent EPA standards for particulate matter as small as 2.5 microns ($PM_{2.5}$) for sources such as jet engine test cells (JETC), diesel engines, generators, incinerators and steam boilers. If effective, the proposed filters will bring a unique combination of particulate removal capability ($PM_{2.5}$ compliant), temperature resistance (900° C), and compactness (more than any other competitive filter) with the ability to be catalyzed for simultaneous collection and destruction of organic particulate and gaseous pollutants.

ACCOMPLISHMENTS: CeraMem has designed, procured, and installed equipment for the fabrication of prototype full size particulate filters. Membrane coating formulations and procedures as well as passageway cementing procedures were developed and full size filters have been produced. A family of three membrane formulations has been developed. These include (a) a durable frit-bonded zirconium silicate, (b) a silica-bonded silicon carbide, and (c) a silicon-carbide-bonded silicon carbide. Membranes with very high fine particulate retention capacity have been developed. The HEPA (high-efficiency particulate air) filter standard is a retention of 99.97% for a dilute 0.3 mm dioctylphthalate (DOP) dilute aerosol. Membrane-coated filter samples have been produced by this research team which have retentions up to 99.999+%. This retention is four to six orders of magnitude superior to a typical diesel filter, which would have a DOP retention <90%. Thus, the retention of the membrane coated monolith filter is remarkably improved higher than existing diesel filters. This filter will remove particulate matter far in excess of the EPA-proposed standard for 2007 of 0.01 g/bhp-hr. This is achieved with an acceptably low clean filter pressure drop at a typical diesel filter space velocity. CeraMem has developed concepts for a unique configuration of monolith diesel filters. A patent application for these concepts has been prepared and filed with the U.S. Patent and Trademark office.

TRANSITION: The proposed ceramic filter technology will yield a Best Available Control Technology (BACT) for specific operational niches such as confined spaces, high temperature duty, and simultaneous removal of particulates, VOCs, and CO, with the potential for additional downstream nitrogen oxide destruction. The transition plan includes licensing the technology to filter manufacturers.

PROJECT SUMMARY

PROJECT TITLE & ID: Reduction of Particulate Emissions from Jet Engine Test Cells Using an Annular After-Reactor; CP-1126

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Norman L. Helgeson; Naval Facilities Engineering Service Center – Port Hueneme, CA

FY 2001 FUNDS: $382K

DESCRIPTION: This project will develop a prototype Annular After Reactor (AAR) jet-engine attachment to reduce particle emissions from jet engine test cells (JETC). The AAR, positioned in the flow path of the jet engine exhaust tube, is simply a hollow pipe which delays mixing of exhaust gases with the surrounding air stream for a sufficiently long residence time to permit incineration of the particulate matter (PM), up to 90%, with minimum pressure drop. With a slight modification, the system may also be adapted for removal of NOx, CO and unburned hydrocarbons.

The project will be carried out in four phases: (1) analytical and computer studies to refine the basic AAR fluid dynamics model and establish design criteria for field tests; (2) intermediate-scale field testing to complete the AAR design; (3) full-scale AAR system fabrication and field testing at a California Naval Air Station; and (4) data reduction and analysis to provide the recommended AAR system for PM reduction. The most challenging technical aspect of this study will be the efficient and rapid mixing, and combustion, of the injected natural gas within the AAR to achieve a proper temperature profile. Excessive pressure drops are expected to be eliminated by using a jet exhaust diffuser on the inlet to the AAR. The challenges of non-steady operating conditions will be addressed by using a feed-forward control system to make required AAR adjustments in concert with programmed changes in engine operating conditions. By maintaining the temperature of the exhaust gases within the AAR at 2000F, it is believed the generation of nitrogen oxides within the AAR will be insignificant.

BENEFIT: The DoD and DOE need new, cost-effective technologies to comply with the proposed, more stringent EPA National Ambient Air Quality Standards (NAAQS) for particulate matter below 2.5 microns ($PM_{2.5}$) for sources such as JETCs, and future National Emission Standards for Hazardous Air Pollutants (NESHAP) specific to JETC emissions. If demonstrated to be effective, the AAR is a minimum-capital-cost, minimum-operating cost approach for reducing PM emissions from JETCs.

ACCOMPLISHMENTS: Sub-scale JETC testing developed data for characterizing AAR pressure drops, augmentation ratios, engine back-pressures, and AAR combustor stability and performance. Sufficient data was obtained to provide a basis for verifying AAR fluid dynamic performance. Combustion tests were conducted to determine the combustion stability of flames on the gas injector in the AAR and tests to measure noise attenuation of several configurations of the AAR were undertaken. The sub-scale AAR noise attenuation measurements to date confirm, in general, the earlier measurements indicating noise reductions of 5 to 15 db.

The one-dimensional compressible exhaust flow program developed last year was improved and validated using the sub-scale AAR air entrainment data. Local pressures and velocities predicted by this one-dimensional model also agreed well with detailed CFD simulations in replicating experimental conditions. These results confirm that the one-dimensional compressible flow program can be used as a scale-up and design tool for establishing the design basis for intermediate- and full-scale AARs. Scale-up of the AAR inlet design was successful as evidenced by the field performance of the small-scale diffuser. A small-scale AAR was designed, fabricated, and tested at the PMNAS. The small-scale tests confirmed the sub-scale test results in showing minimal back-pressure effects of the AAR on the engine.

A conceptual design of the intermediate-scale AAR was simulated using the 1-D compressible flow program to generate parametric curves that provide a basis for design specifications. A conceptual design of the full-scale AAR was also simulated for military and after burning power levels using the compressible flow program. Like the intermediate-scale studies, all of the proposed wall/cooling scenarios produced structural temperatures well within material thermal design limitations.

TRANSITION: The Army, Navy and Air Force have each expressed an interest in application of this proposed technology. In addition to JETCs, this technology has the potential to transition to other stationary and mobile sources of combustion emissions.

PROJECT SUMMARY

PROJECT TITLE & ID: Thermal Actively Controlled Sludge Treatment; CP-1132

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Tim Parr; Naval Air Warfare Center – China Lake, CA

FY 2001 FUNDS: $450K

DESCRIPTION: This project proposes a system that addresses the sludge disposal problem onboard Navy ships by using a unique, highly compact and high performance combustion process. The project's objective is to develop a two-stage incineration process comprising: (1) a primary vortex containment combustion (VCC) process, which also separates and retains particulates; (2) a self-propagating, high-temperature synthesis (SHS) thermal processing and encapsulation process for treatment of resultant ash; and (3) an actively controlled and monitored after-burner (AB) process for emissions reduction. The process can be automated and integrated into a comprehensive, continuously operated, oily water treatment system.

The technical approach builds on the compact, closed-loop controlled waste incinerator for blackwater successfully developed in previous SERDP projects CP-034 and CP-887. The project consists of six developmental phases: (1) fundamental laboratory-scale studies (injection, swirl design, flame stability, laser diagnostics, modeling, ash treatment) on surrogate sludge waste mixtures; (2) VCC and AB integration schemes; (3) conceptual design; (4) scale-up and testing of practical embodiments under full-scale conditions; (5) integration of monitoring and automatic active control schemes; and (6) testing requirements definition for future transition to a demonstration/ validation program.

BENEFIT: The Department of Defense (DoD) currently makes wide use of oil/water separators (OWS) to remove oil from a variety of aqueous waste streams prior to discharge. On-site or shipboard methods to treat or reduce the volume of accumulated sludges generated by these OWSs are required to eliminate sludge transportation costs for offsite disposal, to reduce downtime for maintenance, and to increase separator efficiency. The Navy is spending about $24M per year to treat 1 billion gallons of bilge oil which includes its storage, off-loading, on-shore treatment, transportation, and off-site disposal. This technology could significantly reduce costs with on-site disposal, either on shore facilities or, for larger vessels, on-board ship. Other advantages of on-site disposal include the increasing costs of off-site disposal, reducing assumed liability of third party disposal, eliminating waste handling and transportation, and avoiding costs for improper field disposal.

ACCOMPLISHMENTS: The project team integrated the VCC LC with the afterburner using low pressure-loss de-swirl design. High VCC/AB performance was demonstrated with low CO and UBH (unburned hydrocarbon) emissions using water as sludge surrogate plus alcohol as a VOC (volatile organic compounds) surrogate. The project team also achieved the VCC flame stability goal with 50 GPH sludge (water) and determined required design changes to achieve the sludge-to-VCC fuel goal of six.

Diagnostics were developed for VCC Test Unit to determine evaporization limit and flame out limit. The sludge (water) mass flow goal was achieved in the VCC by optimizing sludge injection angle, sludge atomization characteristics, number of sludge and auxiliary diesel fuel injectors, and type of diesel fuel injector.

The waste sludge acceptance criteria was broadened for the full scale VCC and the prescribed goals were achieved for the sludge surrogates such as water, water plus oil, and water plus volatile solids. The CO, Total Hydrocarbons, and NOx emissions were significantly below the IMO limits. Complex surrogate sludges were evaluated, including organic solids, oil, and water mixes, which will lead to practical applications for real sludges. VCC design changes were made to improve solids retention (trapping) efficiency. The subscale closed-loop active control work was initiated with the adaptive fuzzy logic combined with system identification.

TRANSITION: The user community will be involved throughout the development of the proposed work. Navy organizations, and the Army and Air Force have also expressed interest in the new sludge treatment system for potential application to a Deployable Waste Disposal System.

PROJECT SUMMARY

PROJECT TITLE & ID: Purification of Oily Wastewaters by a One-Step Advanced Biodegradation Process that Produces No Secondary Wastestreams; CP-1136

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Harris Gold; Foster-Miller, Inc. – Waltham, MA

FY 2001 FUNDS: $604K

DESCRIPTION: The overall objective of this project is to demonstrate a low maintenance biological process for onboard treatment of bilge water to meet the 15 ppm International Maritime Organizations Marine Pollution Convention (MARPOL) oil discharge provision and in which the oil contaminants are completely degraded to carbon dioxide and water.

A new technique, called forced molecular evolution, will be used to cultivate enhanced optimized microorganisms needed for a robust, high throughput biological process with performance, size and maintenance characteristics suitable for shipboard deployment. The method has two steps: (1) a whole-cell, mutagenic selection technique to rapidly cultivate broadly non-specific bacterial strains tailored to the pressures imposed by the wastewater, and (2) a genetic enhancement technique to further optimize and tailor the degradation capability of the selected bacterial strains.

The other major part of the program involves the development of a new bioreactor to treat the bilge water to meet the MARPOL discharge requirements. The approach that will be taken is to try to retrofit existing oil/water separators (OWS) to achieve the high oxygen rates and reduce the costs of implementation.

BENEFIT: The immediate environmental benefit derived from this program is the development of a new technology platform that is applicable to a widely diverse set of Department of Defense (DoD) and industrially related environmental problems. The methods and designs that will be developed are immediately applicable to current DoD needs. At the conclusion of this project, microbial consortia will be available for the treatment of bilge water and for wash rack and wash down waters from DoD maintenance facilities. In addition, a small pilot plant bioreactor system will be available to evaluate various DoD-generated wastewaters. The potential savings to the DoD for the long term would be about $25 million annually with about 10 percent related to a reduction in maintenance costs and 90 percent related to a reduction in the costs of disposing of the separated oil. It is also expected that the design of the new bioreactors would be based on retrofitting existing oil/water separators (OWS) to achieve high oxygen demand rates and reduce the cost of implementation; this latter cost reduction has not been estimated.

ACCOMPLISHMENTS: The collection of microorganisms samples from Navy sites and the diversification of initial microflora and screening of microorganisms for pathogens were completed. The mixture of microbial consortia were subjected to a gradual increase in the selection pressures in a simulated seawater oily-waste fermentation medium. The results obtained thus far indicate that the organisms are robust in terms of survival under extreme conditions and are stronger in terms of oil degradation during the latter phases of the selection process. Biodegradation results of batch and continuous and selection studies were found to be comparable.

Samples were transferred to Tufts University for genetic enhancement studies. Efforts have focused on cloning and characterization of the naphthalene degradation genes for molecular evolution and subsequent introduction into the bioreactor. Studies were also carried out on standard Navy bilgewater simulant to determine the degree of biodegradation. A listing of microbial oil-degradation plasmids and genes has been compiled and plasmids that are known to encode enzymes involved in degradation of oil components have been identified.

Tests were carried out on the biodegradation capabilities of the microoganism consortia developed at the end of the Stage 8 selection studies. The rates of hydrocarbon degradation by these consortia were compared to those obtained with the oil-contaminated soil sample. One consortium was capable of 8 percent biodegradation of the initial hydrocarbons, or approximately 0.3 g hydrocarbon per liter per day. The microorganisms of the same consortium were capable of degrading both alkanes and PAHs.

TRANSITIION: Foster-Miller has initiated a teaming agreement with Enviroenergy Systems International, Inc. (ESII) of McLean, VA for the development and commercialization of the kinetically-enhanced optimized microorganisms for the treatment of oily wastewaters generated by DoD operations. ESII will manufacture and market both the microorganisms in a dry powdered form and the bioreactors. Upon successful completion of the SERDP effort, sufficient information will be available to initiate scale up and field testing of the prototype products(s) possibly through ESTCP or other demonstration funding process.

PROJECT SUMMARY

PROJECT TITLE & ID: Distribution and Fate of Energetics on DoD Test and Training Ranges; CP-1155

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Judith Pennington; U.S. Army Corps of Engineers Engineer Research and Development Center, Environmental Laboratory – Vicksburg, MS

FY 2001 FUNDS: $740K

DESCRIPTION: The primary objective of this project is to provide the Department of Defense (DoD) with techniques to assess the potential for groundwater contamination from residues of high explosives (TNT, PETN, RDX, and HMX) at testing and training ranges. Results of the project will facilitate informed management decision making, minimize environmental impacts of testing and training, and contribute to continued operation of ranges. The initial tasks will be to identify the energetics composition of formerly and presently used munitions and assess the kinds and numbers of unexploded ordnance (UXO) that can be expected at various types of ranges. The research team currently possess a listing of UXO recovered from two major firing ranges and is in the process of augmenting this information with data from other sites. Procedures for determining the concentration and distribution of post blast residues will be based upon methods developed from previous sampling of ranges. Methods developed in the Defense Advanced Research Projects Agency (DARPA)-sponsored Dog's Nose project on chemical detection of landmines will be used to characterize low levels of post blast residues.

Once the composition of post blast residues including environmental transformation products of explosives is evaluated, which may be produced by both primary and secondary charges in munitions, environmental transport parameters will be developed and the distribution and concentration of the residues at ranges will be determined. Transport parameter studies will concentrate on main-charge explosives, their transformation products, and explosives residues for which fate and transport process descriptors are nonexistent. On-going research at testing and firing ranges will facilitate identification of research sites and access to records and ranges. Firing histories, fate and transport characteristics of explosives residues, and the distribution and concentration of the residues will be used as input for simulation models to evaluate impacts to soil and groundwater. Because of the extreme heterogeneity expected, special attention will be given to methods for collecting representative samples on ranges, including guidance concerning experimental design, and statistical techniques.

BENEFIT: The results of this project will contribute to an understanding of key processes affecting the potential for explosives residues to impact the environment. Project results will document activities at test and training ranges that have the potential to cause groundwater contamination by residues of high explosives. Immediate benefits will include guidance for characterizing contamination efficiently and cost-effectively, tools for anticipating the potential for environmental impacts and for demonstrating responsible management of facilities to sustain their use for testing and training. These methods could result in substantial cost saving for site characterization, and sustained use.

ACCOMPLISHMENTS: A database for the explosives content of more than 30 of the most commonly encountered mortars, grenades and artillery munitions on Army training ranges was extracted from a more comprehensive search of the MIDAS database and other sources. The data include item caliber, model identification, and chemical composition in percent of total charge weight. TNT and RDX predominate the composition in this group, but HMX and PETN are also present. These data together with published dud and low order detonation rates will be used to estimate the explosives loading at the sampling sites. Historical firing records for the last three years were obtained and will be used to correlate what was fired with what was found on the ranges.

A summary of data gaps in primary fate and transport data was prepared. The table includes the principal high explosives and propellants, and their degradation/transformation products. The disappearance rate coefficient for nitroglycerine was determined.

Soil was sampled at a large, heavy artillery impact range and in one bay of a hand grenade range. Surface soil samples were collected in front of two 105-mm howitzer firing points and at distances as far as 20 m from the muzzle. The major propellant-related contaminant found was 2,4-DNT. All samples had significant levels of 2,4-DNT. Surface soil samples were collected from numerous artillery and mortar impact areas of the artillery range. Concentrations of residues were quite low to not detectable in and around the detonation craters, but concentrations of TNT were very high adjacent to and below ruptured rounds (about 700 mg/kg). Both surface and subsurface (about 6-inch depth) soil was sampled in one bay of the hand grenade range. Concentrations of Composition B related explosives (TNT, RDX, HMX) were high in surface soils and still substantial below the surface.

The project team evaluated two snow-covered ranges for estimating residues of explosives from individual detonations. Results successfully demonstrated that exploding ordnance over an uncontaminated snow cover provides an effective means of (1) visualizing the "fall out" from individual blasts, (2) sampling the residuals without the matrix interferences present on the soil surface, and (3) achieving an analysis free of the contamination resulting from the past history of the site.

TRANSITION: Programs in place at all of the performing organizations will facilitate future widespread application of the procedures to determine the distribution and fate of energetics on DoD test and training ranges. Researchers at the U.S. Army Corps of Engineers Engineer Research and Development Centers' (ERDC) Environmental Laboratory and Cold Regions Research and Engineering Laboratory (CRREL), as well as Sandia National Laboratory (SNL) are actively involved in developing procedures to assess the fate and transport of explosives from UXO. The research team has been advising the National Guard on the complex problems with explosives at the Massachusetts Military Reservation. A demonstration program under the Environmental Security Technology Certification Program (ESTCP) can validate guidance with on-site evaluation and modeling that are developed in the proposed project with which ERDC and SNL have prior experience.

PROJECT SUMMARY

PROJECT TITLE & ID: Determining the Fate and Ecological Effects of Copper and Zinc Loading in Estuarine Environments: A Multi-Disciplinary Program; CP-1156

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Alberto Zirino; Space and Naval Warfare Systems Command – San Diego, CA

FY 2001 FUNDS: $152K

DESCRIPTION: The objective of this work will be to produce a method for estimating the impact of copper and zinc loading in estuarine environments, in specific mixing zones, and throughout entire aquatic basins. Copper and zinc species will be incorporated in a hydrodynamic (physical) estuarine model that simulates the principal estuarine topography, tidally-driven currents, meteorology, and bottom characteristics. The model is used to compute water residence times in the estuary, the key physico-chemical variable against which all other rate-dependant processes are evaluated. Steady-state concentrations of metal species, including the steady-state concentrations of the "free" hydrated metal ion are computed from the hydrodynamic model, using known or experimentally measured input and sedimentation data for the estuary. The computed steady-state concentrations of copper and zinc species are then compared to the experimental data and the model is fine-tuned by adjusting interspecies reaction (rate) constants, until the model is optimized to reproduce the copper and zinc dynamics. The environmental impact of the steady-state concentrations of the toxic copper and zinc species will be evaluated in laboratory tests, as well as through field observations.

The principal investigators from this project will be collaborating with the other two SERDP projects on copper and zinc in estuarine system (CP-1157 and CP-1158) and with other Navy projects working in this subject area in an effort to foster close cooperation and exchange of information. In addition, the three SERDP projects will develop unified sampling and analysis techniques.

BENEFIT: This program will benefit the Department of Defense (DoD) and broader environmental compliance by: (1) the methods and data developed will be important to the DoD Uniform National Discharge Standards Program (UNDS); and (2) the information from this project will be transitioned to DoD environmental managers dealing with facilities and dredging compliance issues. The science resulting from the project should provide a basis for DoD to work with Environmental Protection Agency (EPA) in developing water quality criteria which account for the importance of metal species and complexation on toxicity. Finally the scientific approach developed under this program can be used as a model for supporting development of reasonable criteria and standards for other metals and contaminants.

ACCOMPLISHMENTS: Two differing types of copper ion selective electrodes (ISE's) were tested for use on marine survey craft: the original Orion(TM) jalpaite Cu-ISE and a chalcogenide glass electrode. Although the electrodes performed similarly, the chalcogenide electrode was more responsive (reversible) to copper activity and, possibly, also more accurate. A preliminary predictive model for copper activity in San Diego Bay was developed from input and speciation data available in the literature. Dispersion coefficients were derived from the salinity field and "tidal pumping" was modeled as a dispersive phenomena. Copper speciation was coded into the model and preliminary runs indicate that the model is functioning as expected.

The SPAWAR, University of Wisconsin - Madison, and the University of North Carolina - Wilmington intercomparison of trace metal speciation techniques was initiated. Laboratory experiments were carried out to develop a system to measure Cu and Zn in seawater with the automated analytical system (TMA) at pH 8. The R/V ECOS was deployed in the first bay-wide monitoring expedition of this program. A cursory look at the data indicates that the copper distribution in the bay is consistent with the proposed mixing model and that the natural complexation capacity of the bay water varies with hydrodynamic residence time.

TRANSITION: The products of this project will be transitionable to the Environmental Security Technology Certification Program with proposed joint funding from the Navy's 6.4 Shoreside Pollution Abatement Program. Technology transfer will be through peer-reviewed journals, technical reports and symposia. A workshop was held in Nov. 2000, co-sponsored by the Navy Applied Research 6.2 Program, to address copper and zinc technical and regulatory issues.

PROJECT SUMMARY

PROJECT TITLE & ID: Speciation, Fluxes, and Cycling of Dissolved Copper and Zinc in Estuaries: The Roles of Sediment Exchange and Photochemical Effects; CP-1157

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Stephen Skrabal; University of North Carolina – Wilmington, NC

FY 2001 FUNDS: $110K

DESCRIPTION: The goals of this study are to: (1) quantitatively determine water column concentrations and benthic fluxes of total dissolved (TD) copper (Cu) and zinc (Zn), dissolved Cu- and Zn-complexing ligands, and ancillary parameters at two sites in the Cape Fear Estuary, NC; (2) determine changes in cycling, fate, and organic speciation of dissolved Cu and Zn that may occur during resuspension events, focusing on the role of photochemical reactions; and (3) examine the effects of a large-scale dredging project on the speciation, fate, and cycling of Cu and Zn in estuarine waters and sediments.

Sediment and water sampling will be conducted primarily at two sites, each of which are subject to shipping and berthing activities representative of Department of Defense (DoD) harbor facilities. Water column samples at the surface (~2 m depth) and near the bottom (1-2 m above the sediment surface) will be collected and filtered in the field using a clean pumping and filtration system. Benthic fluxes of TD Cu and Zn, dissolved Cu- and Zn-complexing ligands, and dissolved organic carbon (DOC) will be measured using a core incubation technique. Controlled photolysis experiments will be performed on sediment suspensions.

The principal investigators from this project will be collaborating with the other two SERDP projects on copper and zinc in estuarine system (CP-1156 and CP-1158) and with other Navy projects working in this subject area in an effort to foster close cooperation and exchange of information. In addition the three SERDP projects will develop unified sampling and analysis techniques.

BENEFIT: The proposed project will provide a large number of direct measurements of benthic fluxes of Cu and Zn and their complexing ligands, and quantify the contribution of benthic fluxes to the amount of complexed Cu and Zn and of Cu- and Zn-complexing ligands in harbor waters. This project uniquely proposes an examination of photochemical effects on Cu and Zn speciation in estuaries and harbors. The results of this project can be used to develop scientifically-based standards for Cu and Zn in the aquatic environment.

ACCOMPLISHMENTS: Intercalibration samples were obtained from the Cape Fear Estuary and San Diego samples and distributed to all copper/zinc project PIs for intercalibration of Cu speciation techniques. Two preliminary experiments were completed in which Cape Fear estuarine water was exposed to ambient solar radiation to examine irradiation effects on Cu speciation. Two additional surveys of the Cape Fear were completed for measurements of Cu and Zn speciation. Coupled with previous work funded separately, 2 years worth of data on metal speciation in the Cape Fear are available to provide a strong background for research on benthic fluxes and photochemical transformations.

The photochemical apparatus was installed and readied for analyzing Cape Fear estuary water samples, including fractionation of organic-rich estuarine water using tangential cross-flow ultrafiltration, with subsequent examination of copper speciation in the different size fractions. The project team also continued surveys of the Cape Fear estuary to understand "baseline" conditions for metal speciation. A preliminary experiment was performed to determine benthic fluxes of copper and copper speciation in a marginal estuarine sediment. The project team met with researchers from the other two SERDP copper/zinc projects to plan collaborative efforts on intercalibration exercises and cooperative sampling efforts.

TRANSITION: The data presented by this project will provide information on the potential amelioration of Cu and Zn by dissolved organic ligands in harbors and estuaries. This data can be used by DoD to evaluate water quality compliance criteria that are based on environmentally relevant impacts of metal discharges, and hence to ensure that economic resources devoted to environmental monitoring and compliance are most efficiently utilized.

PROJECT SUMMARY

PROJECT TITLE & ID: Speciation, Sources, and Bioavailability of Copper and Zinc in DoD Impacted Harbors and Estuaries; CP-1158

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Martin Shafer; University of Wisconsin – Madison, WI

FY 2001 FUNDS: $265K

DESCRIPTION: The overall goal of this project is to advance the current understanding of the fate and impact of copper and zinc in harbors and estuaries. Specifically, it will develop a quantitative understanding of the speciation, bioavailability and fate of important metal species transported to and found within Department of Defense (DoD)-impacted harbors. The objectives of this project are to: (1) apply and refine methods for speciation of copper (Cu) and zinc (Zn) in harbor and estuary waters; (2) assess the influences of environmental factors and processes on the speciation and fate of Cu and Zn; (3) interpret experimentally determined lability estimates of dominant metal-complexes in terms of time scales relevant to biological and physical processes in DoD impacted harbors; (4) compare modeled estimates of bioavailability of specific phases with biochemically determined exposure on experimental organisms; and (5) determine sources of Cu and Zn to harbors and estuaries using a multi-faceted approach of selective sampling, metal phase discrimination, and unique stable isotopic signatures to distinguish DoD sources of Cu and Zn from other sources to harbors and estuaries.

The intent of this project is to isolate functionally distinct metal "pools" within harbor systems and characterize the lability of Cu and Zn within these pools. The nature and sources of ligands in specific pools will be determined by chemical and biochemical means. Measurements of liability in specific pools, as defined by chemical and physical speciation techniques will be complemented and validated by bioassays at both the molecular and organism level. Stable isotopes of Cu and Zn will be explored as tracers of source and source specific bioavailability.

The principal investigators from this project will be collaborating with the other two SERDP projects on copper and zinc in estuarine system (CP-1156 and CP-1157) and with other Navy projects working in this subject area in an effort to foster close cooperation and exchange of information. In addition the three SERDP projects will develop unified sampling and analysis techniques.

BENEFIT: These findings will allow the development of a method for the assessment of the potential of Cu and Zn to impact biological communities. This work, therefore, will have direct bearing on the establishment of water quality criteria in these systems. This study will provide a crucial test of the applicability of stable isotopes to aid in source reconciliation and bioavailability studies. Important parameters will be established from which the precision of source assignment can be assessed. Source tracing and apportionment using stable isotopic signatures should have broad applicability to both aquatic and terrestrial DoD sites and the exploratory work in this study will provide that assessment.

ACCOMPLISHMENTS: A sampling program incorporating planned fractionation and speciation techniques was undertaken at the Norfolk and Wilmington field sites. Five sites were sampled within the Norfolk harbor/estuary system, and four sites within the Wilmington system. Chelex kinetic separations were performed at all nine sites, as were bioassay experiments with two species of marine algae. Other samples collected included those for trace metals (including Cu and Zn), metal stable isotopes, dissolved organic carbon, sulfide, thiols, pigments, and suspended particulate matter.

An intercomparison study was conducted to improve and understand the comparability of electrochemical metal speciation measurements performed by the three principal research groups working on the Cu and Zn issue. Two sites (samples) were selected: San Diego Harbor and (2) Cape Fear, NC. Large composite samples were collected and trace metal clean techniques were followed throughout. A wide spectrum of techniques were applied to maximize information about the natural ligands and to ensure comparability with other researchers. Modeling of the titration results was conducted to determine the concentration of natural ligands and their conditional stability constants. Results demonstrate that concentrations of strong and moderately-strong Cu(II) ligands were higher than total Cu concentrations in samples from both Cape Fear and San Diego, indicating that the free Cu(II) levels are exceedingly small.

Three species of common marine algae were chosen to develop bioassay techniques that are reliable probes of Cu speciation and therefore bioavailability. Early experiments focused on optimizing culture media (Aquil), determining algal growth characteristics, and obtaining data on critical cell properties, such as mass per cell as a function of growth stage. Very preliminary bioassay probes of Cu availability in San Diego Bay and Cape Fear waters were conducted and these experiments indicated that a much smaller fraction (5%) of the total copper was available to the organisms in Cape Fear, than in San Diego (27%), a finding consistent with the greater Cu ligand levels in Cape Fear (as determined by voltammetry).

Work was completed on the task to develop a rapid, contamination "free", totally automated method for analysis of copper (and many other trace elements) in marine systems. A method based on automated solid phase chelation, using immobilized iminodiacetate was evaluated and validation studies with oceanic reference water standards show excellent results. Detection limits are in the range of 0.08 - 0.16 nM, with blanks typically contributing less than 3% of total sample signal.

TRANSITION: The technology underpinning the method of assessing the potential of Cu and Zn to impact biological communities should be readily transferable to DoD or DoD contractors. Data developed on Cu and Zn sources to, and within, the study systems will be used to construct or refine mass balances of metal loading. When coupled with information generated from this study, on source specific metal availability, appropriate resources can be directed to controlling inputs with the greatest potential for ecosystem impact. Recommendations along these lines will be prepared for DoD, which may then use these data in future permitting applications. DoD can use information from this project to determine whether stable-isotope technology should be applied to other impacted sites.

PROJECT SUMMARY

PROJECT TITLE & ID: A Predictive Capability for the Source of Terms of Residual Energetic Materials from Burning and/or Detonation Activities; CP-1159

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Brown; Aerodyne Research, Inc. – Billerica, MA

FY 2001 FUNDS: $276K

DESCRIPTION: The overall goals of this project are to: (1) understand and quantify the major chemical and physical processes, such as afterburning effects, and formation and deposition of particles; (2) develop a Source Characterization Model (SCM) for predicting accurately the source terms resulting from the burning and detonation of munitions, including both gaseous and particulate species; (3) link the SCM output to appropriate fate and transport models in air, soil, or water medium; and (4) validate the final SCM against a few typical scenarios. This project will develop the SCM and related databases and link them to available dispersion and transport models. The input to the SCM will include munitions or energetic identity and weight, ambient site conditions, and site-specific conditions for the open burn/open detonation (OB/OD) or use of munitions. The SCM will include algorithms, supporting databases, and a graphical user interface for the prediction of chemical identities and emission factors, particle size and deposition, plume buoyancy, and plume size at final rise. The output of the SCM will be used as input conditions to existing transport and dispersion models in air, water, and the ground surface.

BENEFIT: The estimated benefits to the Department of Defense (DoD) are cost reduction by modeling and cost of incomplete responses to regulatory concern. The total cost of emission characterization by testing for an estimated 400 unique munitions could cost DoD from $0.5 billion to $1 billion. Assuming that only 1 in 20 munitions requires testing and the rest can be modeled, the savings from modeling could exceed $475 million. Typically an installation may spend up to $2 million monitoring groundwater and sampling soil in order to satisfy regulators and the public that munitions use or OB/OD has no impact to human health or the environment. The development of a capability incorporating testing data and the prediction of chemical species of concern is expected to reduce regulatory requirements for testing and monitoring.

ACCOMPLISHMENTS: The project team began detonation emissions measurements at Aberdeen Proving Ground (APG) which will provide data for a number of gas phase species and particulates. A plume dynamics modeling module was developed based on a Gaussian dispersion approach. This module treats gas dispersion following impact/detonation given a temperature profile and wind speed. The plume dynamics model was based on a review of the EPA approved CALPUFF[1] and ADORA[2] dispersion models for the atmospheric release of hazardous materials. Routines for treating finite-rate chemical kinetics were developed and integrated into the plume dynamics module. These routines are based on the CHEMKIN II chemical kinetics library[3] and the integration algorithm DASSL[4] developed at Sandia National Laboratories.

TRANSITION: The modeling capability developed by this project will be a public domain environmental assessment model. It will be reviewed for acceptance by applicable EPA offices involved in emissions modeling. Subject to EPA approval, it will be made available through the EPA regulatory support electronic bulletin board. The project results will be presented to potential users via journal articles, symposia, and technical reports. The potential users include all DoD, DOE, and EPA activities involved in OB/OD. User guides and technical description of the capability will be released by Aerodyne Research in interim and final forms during the project. The developed capability, as a readily available and off-the-shelf product, will be user-friendly and run on a PC under Microsoft Windows.

PROJECT SUMMARY

PROJECT TITLE & ID: Use of a Nafion Membrane Probe for Quick, On-the-Spot Determination of Ionic Copper Contamination Levels in Natural Waters; CP-1160 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. John Foerster; U.S. Naval Academy – Annapolis, MD

FY 2000 COMPLETED PROJECT

DESCRIPTION: The objective of this project was to develop a user-friendly detection system that allows for the rapid assessment of the major ionic copper ions in the marine environment. Emphasis was on those ionic copper species [Cu(I) and Cu(II)] which may adversely affect the marine environment. The overall goal of the project was to prove the concept of an ionic copper probe that has parts per billion (ppb) detection limits, and is easily used by dockside personnel having little to no formal chemical analysis training.

The copper sensing probe uses polymer technology with an impregnated color indicator. The active component of the probe is comprised of the polymer Nafion 117. The polymer is impregnated with a copper (I) metal ion organic complexing agent, 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (Bathocuproine or BCP), and attached to a plastic panel. The panel is immersed in a known volume of water suspected to contain copper (I). After 20 minutes, the test panel is removed from the solution and the active component of the tester (Nafion film and BCP) is compared to the color panel on the tester. A relative concentration of copper (I) can be determined. BCP reacts with Cu(I) to give a very intense, visible and stable orange-complex with a unique spectroscopic signal. By adding a reducing agent, Cu(II) can be measured.

BENEFIT: A simple to use, inexpensive ionic copper monitoring system will aid in the implementation of the Uniform National Discharge Standards (UNDS) Act which will mandate some form of sensor/detection system that can address the role of speciation [Cu(I) and Cu(II)] marine environments.

ACCOMPLISHMENTS: The project team developed a simplified ionic copper detection device/method for use in Navy harbor waters. A dosimeter probe composed of the polymer Nafion 117 was impregnated with and without Bathocuproine (BCP) to assess its sensitivity to Cu(I). The proof-of-concept was demonstrated with the response to, and absorption of, Cu(I) by the membrane. The device contains comparator strip that indicates the concentration of ionic copper as a function of the color of the comparator.

TRANSITION: This project is a cooperative study between the Oceanography Department of the U.S. Naval Academy and the Environmental And Sensor Chemistry Section, Chemistry Division of the Naval Research Laboratory. UNDS has identified 25 discharges requiring Marine Pollution Control Devices (MPCD). Three of these discharges that can be monitored with the Nafion Membrane Probe are: (1) hull coating leachate; (2) seawater cooling overboard discharges; and (3) underwater ship husbandry. Possible funding to continue scale-up production of the Nafion Membrane Probe via NAVSEA is a very good possibility once the proof-of-concept has been shown. Another possible funding source/user of the probe would be various state agencies that would probably require monitoring capabilities in the marine environment in support of UNDS.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of $PM_{2.5}$ Dust Emissions from Training/Testing Range Operations; CP-1190

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Veranth; University of Utah – Salt Lake City, UT

FY 2001 FUNDS: $172K

DESCRIPTION: This project will conduct field measurements and laboratory analyses of windblown dust and road dust resulting from troop operations at arid sites in the western United States. The goal of this study will be to provide installation-level environmental staff with scientifically validated information for developing emissions inventories, environmental assessments, and cost-effective dust control measures that are compatible with mission readiness. Source samples, laboratory analysis of these samples, development of advanced sample analysis techniques, theoretical modeling, and measurement of field emissions and receptor site particulates constitute the major components of this study. The study is based on two hypotheses developed from previous studies of dust emissions in arid climates. Only a small fraction of the dust that is initially suspended is actually transported long distances. Dust emissions from various sources potentially contain marker species that are present at higher concentrations than the regional background, and these markers can provide sensitive methods for quantifying the contribution of various source categories to the particulate collected at receptor sites. The experimental program will test these hypotheses with an integrated program of sampling dust at multiple locations and elevations above grade during selected troop operations on unpaved roads or cross-country trails.

BENEFIT: The direct products of this study will include (1) a critical evaluation and review of source characterization, dust emission inventory, and transport modeling technology applicable to training/testing range operations, and (2) technical papers regarding field measurement, sample analysis, and data reduction methods. Based on the detailed sampling and analysis in this study, specific recommendations will be made regarding appropriate methods for routine use in dust characterization studies.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: The direct products of this study will include a critical evaluation and review of source characterization, dust emission inventory, and transport modeling technology applicable to training/testing range operations and technical papers regarding field measurement, sample analysis, and data reduction methods. This technology will be transferred to potential users by the investigators and by members of an advisory panel.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterizing and Quantifying Local and Regional Particulate Matter Emissions from DoD Installations; CP-1191

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Gillies; Desert Research Institute – Reno, NV

FY 2001 FUNDS: $434K

DESCRIPTION: Military activities on Department of Defense (DoD) installations in the southwest U.S. are potentially large contributors of wind-blown dust due to the presence of large expanses of fragile desert soils and via testing and training activities. Particulate Matter (PM) emitted by these activities impacts vehicle performance, and threatens the health and safety of military personnel due to inhalation of PM and loss of visibility. This project proposes a systematic, empirically based research approach that combines environmental monitoring and field experimentation to quantify and characterize PM emissions from testing and training.

Contributions from dust and other sources will be measured during a 1-year ambient air quality monitoring program at upwind and downwind boundary flux sites, combined with 14 days of intensive monitoring during periods of active training. An emission factor database will be developed using upwind-downwind monitoring methods to measure vehicle-generated emissions using fast-response instrumentation. Potential long-range transport of the emitted PM will be assessed from field experiments. Potential visibility degradation off-post will be determined with an intensive field measurement campaign.

BENEFIT: Specific benefits from the research include: (1) the development and demonstration of a methodology that will identify contributions of PM from specific on-post sources to the flux of PM exiting installation boundaries; (2) the development and demonstration of a methodology to define emission factors for military vehicles and an emission factor data base that can be used in a model to estimate the contributions from different sources within an installation for various testing and training scenarios; (3) a model to convert the horizontal emission flux to vertical emission flux that will allow the emission inventory data to be utilized in dispersion models to estimate the long-distance transport potential of the emitted PM; (4) the demonstration of the TRAKER approach to determine horizontal emission fluxes and its effectiveness to map the emission potential of different surface types with great economy, and (5) characterize and quantify the emissions from the military activities.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: The acquired information can be transitioned to Integrated Training and Management (ITAM) personnel who may be given the mandate to deal with certain aspects of the dust and PM emission problem.

PROJECT SUMMARY

PROJECT TITLE & ID: Fundamental Studies of Air Emissions from DoD Munitions and Novel Approaches for Their Detection; CP-1193

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Thomas Brill; University of Delaware – Newark, DE

FY 2001 FUNDS: $143K

DESCRIPTION: The release of toxic gases resulting from various peacetime military activities has become a problem of increasing concern for human health and the environment. The EPA and other organizations are paying particular attention to Toxic Release Inventory (TRI) air emissions from munitions at testing and training ranges on land and sea. A major challenge is that there are hundreds of chemicals on the TRI list and that the identification and characterization of their emissions from DoD munitions, such as from firing and exploding ordnance is very difficult and expensive. This project will generate a fundamental understanding of the reaction chemistry of munitions using one-of-a-kind laboratory facilities. By understanding the actual reaction chemistry resulting from mixing with ambient air, the research team will gain significant insight into the major chemical pathways, and will also identify pathways that do not occur, thus indicating classes of TRI compounds that are not generated. State-of-the-art chemical sensors will be developed for real-time field use. Physics-based computational fluid dynamics (CFD) models will be developed to simulate the mixing of the product gases and particles from the energetic event and their subsequent reaction with ambient air. This will aid in describing the emission plume relative to the volume of the plume, the emission constituents, and the distribution of the constituents within the plume. A key component of the project is the integration of this research with the ongoing work at the Aberdeen Test Center (ATC) on characterizing firing point emissions within their specialized test facility. The work at ATC concerns the capture, identification, and analysis of multiple emissions from small arms, tank cannons, howitzer cannons, mortars, rockets, etc. This will allow for calibration of the sensors and the validation of the project's models. The culmination of the work will be the real-time identification and characterization of toxic gas emissions from actual open field gun firings.

BENEFIT: One benefit of this project is the development of hardware and related models that can be used to identify and characterize TRI emissions from DoD munitions in real-time and in the open field. Other benefits include the identification of classes of emission factors as a function of source type and the assessment and understanding of temporal and spatial variability of the emissions.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: The products of this research include: (1) The first-ever real-time data on TRI emissions from open field weapons firing; (2) the development of a firing point emissions CFD model that can be applied to various weapons as a means for calibrating the chemical measurements made by field sensors; (3) the development of advanced laser-based real-time field sensors that can be used in a wide variety of DoD munitions emissions applications; and (4) a much better understanding of the chemical pathways that may or may not result in the formation of TRI emissions for various classes of munitions/source types. The team will actively work with the AEC Range XXI office to transition the products most effectively throughout the DoD munitions emission community. The emissions data created will be used to feed fate transport and effect models.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of Scrap Metals for Mass Detonating Energetic Materials; CP-1194 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. James Phelan; Sandia National Laboratories – Albuquerque, NM

FY 2001 FUNDS: $100K

DESCRIPTION: This research project intends to explore the concept of an automated screening process to help characterize scrap materials for the presence of mass-detonating energetic materials. The current practice of visually screening large amounts of scrap materials is inefficient and has misidentified mass detonating quantities of explosives causing significant equipment losses during scrap recycling operations. The concept of an automated screening process using chemical sensing technology has the potential to provide an efficient low cost method to discriminate whether scrap materials contain mass detonating quantities of energetic materials prior to entering a treatment process, and to verify decontamination of surface residues after treatment.

The requirements for a chemical sensor for this application include high sensitivity and selectivity for the chemicals found in the energetic materials, and fast response time to allow real-time sorting. A novel new sensor has emerged from the DARPA Dog's Nose program that meets these requirements. Research at MIT found that fluorescent chemosensors could have significantly increased sensitivity by amplifying the fluorescent quench in a molecular wire approach. This novel amplifying fluorescent polymer (AFP) approach has been developed for the detection of TNT and has been engineered into a sensor system by Nomadics, Inc. While the current Nomadics sensor package has been optimized for detection of TNT, researchers at MIT believe that they can design an AFP for RDX. The project proposes to complete proof-of-concept tests that will determine whether mass detonating quantities of energetic materials can be identified by vapor signature in static bin headspace with the Nomadics amplifying fluorescent polymer sensor. If successful, the magnitude of the vapor signature can be used to develop a conceptual design for a dynamic screening system. The research team will determine the success of the technology by measuring and comparing the absolute sensitivity of the latest Nomadics sensor to vapors derived from water solutions and measured with preconcentrated samples. The team will also perform bin tests and compare analyses from the Nomadics AFP sensor with the Tenax tubes or SPME samples, and extrapolate the data for use of the Nomadics AFP sensor in a dynamic conveyor system.

BENEFIT: This project will determine the proof-of-principle of whether chemical vapor sensing can discriminate mass detonating energetic materials among scrap materials. If successful, this technology could be linked to conveyor belt sorting system to segregate portions of the scrap that likely contain mass detonating quantities of energetic materials, thereby, reducing the amount of scrap material requiring expensive inspection and treatment.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: The opportunity to process large amounts of range scrap to eliminate mass detonating quantities of energetic materials may be feasible with a segmented gate system outfitted with a highly sensitive chemical sensor array. The segmented gate technology is already commercially available, however modifications would be necessary to change from soil processing to scrap processing. An extremely sensitive chemical sensor has emerged from basic research programs that can be adapted for use in the segmented gate system.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of a GIS-Based Complex Terrain Model for Atmospheric Dust Dispersion; CP-1195

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. K. Jerry Allwine; Pacific Northwest National – Richland, WA

FY 2001 FUNDS: $185K

DESCRIPTION: This project will characterize dust emissions from range training/testing activities by: (1) analyzing existing dust characterization data; (2) conducting additional field studies, and (3) developing a geographic information system (GIS)-based complex-terrain atmospheric dispersion model. This modeling system will have several uses including: (1) the near real-time tracking of dust movement given real-time meteorological data and dust generation information, (2) performing air quality assessments, and (3) planning and evaluating training operations and dust control measures under various meteorological scenarios. A primary focus of the proposed research is to develop dust emission factors for range activities and incorporate the dust emission formulations into a U.S. EPA approved air quality model. The GIS-based air quality model will be compatible with available military land management and operational models, and will incorporate the effects of complex terrain on dispersion.

BENEFIT: The atmospheric dispersion model and dust characterization techniques being developed in this project will be broadly applicable to many installations and sites owned by DoD and DOE in complex terrains where soil disturbance and climate result in dust generation and transport. The proposed model will be specifically directed toward, and will be fully-tested and documented for use in, simulating dust dispersion from activities at military testing/training ranges. The air quality model will be able to assess NAAQS and federal Class I area impacts and will be compatible with available military land management and operational GIS systems. The completed modeling system will allow military personnel to specify training/testing activities using a GIS interface, run the atmospheric dispersion model, and then graphically view the dust impacts using a GIS. The model will also have the capability to provide real-time dust dispersion for those sites maintaining real-time weather measurement data. This capability will allow graphic, GIS-based representation of current and projected PM transport and concentration that will enable military staff to modify activities or locations to minimize health and environmental impacts of airborne dust and/or obscurants. With the emphasis on user needs and input during the development of the model, transition to installation operation and use of the model should be greatly facilitated. At the completion of the proposed project, the end product will also include a field deployable time-tagged particle sampler and a documented measurement method for rapid, cost-effective assessment and mapping of roadway dust generation with high spatial resolution.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: The product (dispersion model and dust characterization techniques) will be transferred to military land managers and operational leaders for use during testing and training exercises and operation in order to reduce the generation of dust.

PROJECT SUMMARY

PROJECT TITLE & ID: Removal, Degradation, and Recovery of Energetics Residues from Range Scrap; CP-1196 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Philip Thorne; Applied Research Associates, Inc. – South Royalton, VT

FY 2001 FUNDS: $100K

DESCRIPTION: The objective of this research project is to investigate an exceptionally low-cost, simple, environmentally benign process to treat energetics residues in-situ on scrap materials of virtually any size or type found on training/testing ranges at DoD installations. The process relies on mild, base hydrolysis of energetics at ambient temperatures in a lime-water solution. Organic high explosives (HE) will be degraded to non-hazardous inorganic ions and insoluble polymers that can be readily recovered from the aqueous decontamination solution by sedimentation or filtration.

Experimentation will begin with the simple lime-water solution (1lb of lime/100gal water) that was observed to dissolve and polymerize explosives in a previous study. Modifications to the basic lime-water solution will be investigated in order to increase the dissolution rate of secondary HE. Test materials will include TNT, RDX, HMX and mixtures thereof. Dissolution rates will be determined visually. The goal will be to understand the effect of temperature on dissolution, degradation and polymerization so that a formulation which is effective and predictable at all ambient temperatures in the field can be developed. A second element will identify and optimize conditions for the polymerization and precipitation of HE. Three types of contaminated scrap samples will be prepared: (1) pieces of range scrap coated with HE; (2) HE loaded into small cracks and crevices; (3) HE encased in pieces of metal scrap. Dissolution and polymerization will be evaluated visually and by instrumental methods. The team will develop a scrap treatment protocol based on the optimum lime-water formulation and perform a bench scale demonstration of it.

BENEFIT: The research team will establish feasibility for timely and effective treatment of a variety of critical energetics residues on range scrap using a lime-water formulation. Through a cost analysis performed at the end of the project, they will also have demonstrated that the new technology is more cost-effective than alternative approaches and therefore worthy of implementation at DoD and DOE sites containing "spent" shells and munitions.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: In collaboration with CRREL researchers and other independent evaluators, field demonstrations and validations of the technology will be performed at DoD sites. If the scrap treatment technology proves feasible, support will be solicited from industrial clients to further develop and adapt the technology to their cleanup needs.

PROJECT SUMMARY

PROJECT TITLE & ID: A Field Program to Identify TRI Chemicals and Determine Emission Factors from DoD Munitions; CP-1197

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Chester Spicer; Battelle – Columbus, OH

FY 2001 FUNDS: $604K

DESCRIPTION: At present, published emission factors for munitions activities have been focused on tests conducted for open burning and open detonation (OB/OD) disposal of energetic materials. DoD needs a technology that would allow emission factors for Toxic Release Inventory (TRI) chemicals to be developed for munitions usage during routine testing and training activities.

The overall objective of this program is to demonstrate a methodology for measuring emissions of TRI chemicals from DoD munitions activities, and to apply the method to determine emission factors from munitions activities at DoD facilities. One specific objective will be to assemble and test an instrumentation package capable of measuring pertinent TRI chemicals at DoD sites. A second specific objective will be to measure "point of discharge" TRI chemical emissions from a variety of munitions used in training activities. A third objective will be to measure "point of impact" TRI emissions from a wide range of DoD munitions at an outdoor testing range.

The major focus of the project is the field campaigns, and the project will conduct two types of campaigns. One will focus on emissions from the discharge of weapons (point of discharge studies) and the other on emissions from explosion on impact (point of impact studies). The field campaigns will be conducted at Aberdeen Test Center (ATC). The point of discharge campaigns will make use of an indoor facility which permits firing weapons with capture of the discharge emissions. The point of impact studies will be carried out at one of ATC's outdoor ranges.

BENEFIT: The proposed program is designed to work closely with DoD services to: (1) identify important munitions activities and sites; (2) use existing data and chemical principles to develop a list of target TRI chemicals that will be measured in the field; (3) recommend and deploy innovative state-of-the-art field monitoring technologies; and (4) collect real world data on munitions emissions for important munitions activities under a range of actual field conditions at field sites. These data will advance the state of knowledge of the nature and quantities of emissions from munitions activities and will help DoD meet its EPCRA reporting requirements by providing more accurate estimates through the DDS. In addition, the accurate characterization of emissions from these activities will assist DoD in setting priorities for emissions reduction strategies.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: There is a broad interest within DoD in developing a credible method to measure the emission factors that are used to estimate annual emissions, and in applying the method to measure emission factors from significant munitions activities.

APPENDIX C
Conservation Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: Advanced Biotelemetry for Resource Management; CS-759

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. William Seegar; Army Research Laboratory – Aberdeen, MD

FY 2000 COMPLETED PROJECT

DESCRIPTION: The management of threatened and endangered species (TES) is a complex issue for military installations involving the synthesis of diverse types of data to develop practical management strategies. Installations are in need of management tools and plans that provide recommendations to address TES issues based on regional habitat information and assessments. Part of that assessment involves the tracking of wildlife as they move throughout their habitats. This project focused on the development of an harmonic radar with "cross band transponder system" that allows continuous monitoring of extremely small birds for up to two years at distances up to 1000 meter. The technical objective was to develop and evaluate the potential of harmonic radar to track regional and local movements of threatened, endangered, and sensitive species for risk assessment and ecosystem management.

BENEFIT: Cost savings to the military will accrue in several ways. First, application of new methods and techniques will allow more effective study of special status species. Second, application of these methods and techniques will require fewer personnel than in the past. Third, fewer persons in the field for shorter periods will reduce interference with military activities. The near real-time integration of this data collection capability with both Geographic Information Systems (GIS) natural resource information and military land use activities will provide managers with a unique ability to support readiness on installations while managing for conservation and biodiversity. The use of harmonic radar tracking provides DoD and other land managers with sophisticated refinement of field ornithology at a time when there is tremendous pressure to manage and protect many small avian species.

ACCOMPLISHMENTS: This project developed a cross-band transponder system which includes small (1-2 grams), radar-activated VHF transmitters, along with a mobile radar system. The radar system activates the VHF tags on the target species - meaning that the tags only transmit when desired and when field biologists are present to collect the information -- and provides location estimates via an automated computer system for up to 2 years. The research team expects to obtain operational ranges of up to 10-15 km. The tag is mounted on top of a bird's lower back and kept in place by leg harnesses, a loop down and around each thigh. The variant adds an elasticized waist loop for birds with short caudal (tail) sections where there is a risk that the tag could slide off the back of the bird. Development is also continuing on maximizing the output power and efficiency of the VHF transmitter portion of the tag. Tags capable of detection by ear at ground-to-ground ranges in excess of 900 meters have been demonstrated, using an appropriate radio receiver and 3-element Yagi antenna.

TRANSITION: This system provides critical information about the habits, habitats and populations of small birds (and potentially other types of small species), and how land management practices or military training might impact them. Many commercial applications exists for this system including: mitigation of bird strike hazards at commercial airports. All of the technology products from this project are being transitioned to research applications through the University of Maryland's Center for Conservation Research and Technology and other research institutions for commercialization and implementation in the private sector. (visit http://www.ccrt.org/HTML/tech.html)

PROJECT SUMMARY

PROJECT TITLE & ID: Development and Demonstration of a Risk Assessment Framework for Natural Resources on Military Training and Testing Lands; CS-1054

PRINCIPAL INVESTIGATORS & ORGANIZATION: Dr. Keturah Reinbold / Ms. Winifred Hodge; U.S. Army Corps of Engineers Engineer Research and Development Center, Construction Engineering Research Laboratory – Champaign, IL

FY 2000 COMPLETED PROJECT

DESCRIPTION The objective of this effort was to develop a structured, scientifically valid risk assessment framework that can be rapidly and inexpensively applied to assess risks of single, multiple, or cumulative impacts of military training and testing activities on natural resources. The framework, titled "Military Ecological Risk Assessment Framework (MERAF), is based on the U.S. EPA's Ecological Risk Assessment Framework in its broad categories but includes more specific expansion in subcategories to provide a framework more suitable to specific military needs and activities.

BENEFIT: This framework will support a risk-based context which will assist the Department of Defense (DoD) to better conduct training and testing activities while complying with environmental regulations, maintaining training and testing realism, and maintaining stewardship of natural resources. The MERAF can be used to structure a fairly rapid, simple and qualitative scoping of a problem, or an in-depth, integrated risk analysis.

ACCOMPLISHMENTS: The project developed a three-tiered (i.e., programmatic, activity-specific, and site-specific) military ecological risk assessment framework. The first tier or programmatic level encompasses all risk assessment steps at the generic and broadest level. The activity-specific tier uses detailed information specific to a particular military activity. This level of analysis uses ecological process models and military activity models. Both the programmatic and activity-specific analyses are site-independent analysis tools. These level of analysis are used to evaluate general risk associated with plans for new military programs, mission realignments, changes in training doctrine or test procedures, and other decisions that do not involve specific geographic locations. Activity-specific frameworks have been developed (fully and partially) for the highest priority training and testing activities: low-level overflights of fixed-wing and rotary-wing aircraft; use of waterborne ranges for training and testing; and weapons fired at targets. Each framework provides specific activity information and assessment considerations for the selected activities, including definition of the activity, component actions, definition and nature of stressors and their modes of action, potential endpoints, routes of exposure, measures of effects, and guidance on characterization of risks from the specific activity. At the third level, the frameworks is applied to a specific site using site-specific natural resources information, endpoints, and site characteristics. A site-specific demonstration is near completion at Yuma Proving Ground which includes the assessment of helicopter overflights, tracked vehicle movement and artillery firing.

TRANSITION: The MERAF procedure has a nested hierarchical structure which will lend itself well to the development of a computerized MERAF tool. The situation-specific nature of many applications of MERAF require flexibility in the application of models and modeling environments. The Land Management System being developed by ERDC of the U.S. Army Corp of Engineers is a likely and promising modeling environment within which to operate and transition MERAF procedure.

PROJECT SUMMARY

PROJECT TITLE & ID: Analysis and Assessment of Military and Non-Military Impacts on Biodiversity: Framework for Environmental Management on Department of Defense (DoD) Lands Using Mojave Desert as a Regional Case Study; CS-1055

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. David Mouat; Desert Research Institute – Reno, NV

FY 2000 COMPLETED PROJECT

DESCRIPTION: This research developed a methodology for regional management of biodiversity and related ecological, stakeholder, cultural, and environmental resource concerns. The project addressed environmental problems at the regional scale in the western Mojave Desert. The impacts of military and non-military stressors on patterns of biodiversity and related environmental resources were examined. The impacts of future land uses on patterns of biodiversity are modeled as alternative scenarios.

Consisting of four components or phases, this project involved: (1) the development of a Quality Assurance/Quality Control plan and a peer-reviewed experimental design; (2) the initiation of a spatially-oriented data base management and decision support system; (3) the organization of a military and non-military stakeholder group to identify environmental issues and human valuations of the regional ecosystem both within and outside the military context; and (4) identification of military and non-military stressors.

BENEFIT: This project provides DoD with the capability to evaluate impacts of both DoD and non-DoD stressors (such as off-road vehicle use and suburban development) on military activities. Through integrated regional ecosystem management, the military can more effectively negotiate biodiversity and other ecosystem management issues with surrounding stakeholders, ensuring minimal environmental damage while maintaining and enhancing the military mission. The methodology developed by this project provides a critical tool for DoD to address these land use issues both within and outside its fence lines.

ACCOMPLISHMENTS: Digital terrain information, biodiversity information, remotely sensed information, geological and geomorphic data constituted the input to the development and assessment of scenario models. The habitat and management strategies of the Desert Tortoise and other key species were derived and correlated to associated species. Multi-date Landsat and SPOT imagery was used to generate data layers showing land use change, landscape pattern, and (combined with other ancillary data) data visualization products. Existing land use activities and other stressors on habitat and biodiversity were evaluated. Scenario modeling, which shows the probability that patterns of land use will change on a given parcel, was used to extrapolate into the future to define alternative future scenarios of land use for the Mojave Desert Region. Fifteen example alternative futures were developed through the modeling process. Three of these are: (1) a depiction of regional "trends" that incorporates population projections; (2) a depiction of total "build-out" of existing land use plans and policies; and (3) a scenario maximizing the conservation of biological diversity.

TRANSITION: The project team has been actively involved in transitioning and integrating their methodology into other existing SERDP projects including Diagnostic Tools and Reclamation Technologies (CS-1131), Emerging and Contemporary Remote Sensing Technologies (CS-1098), and Effects of Ecosystem Fragmentation (CS-1100). The project presented two workshops to members of the Desert Managers Group at Utah State University. The workshops were designed to help the Desert Managers Group (DMG) to transition the Alternative Futures work to a decision support system. They consisted of hands-on interaction, making use of DMG-generated data sets within the framework of the alternative futures modeling and design system and discussion of how assessment and evaluation of the alternative futures would assist DMG members in environmental decision making. Additionally, efforts have been made to transition the methodology into Integrated Dynamic Landscape Analysis and Modeling System (IDLAMS) and Land Management System (LMS). The team, also, co-hosted the "International Symposium on Advances in Research for Natural Resource Planning and Management Across Regional Landscapes" at the University of New England, New South Wales, Australia. The methodology developed by this project will be implemented to land management issues pertinent to other DoD and DOE installations within the Mojave, as well as, be adapted to other ecoregions.

PROJECT SUMMARY

PROJECT TITLE & ID: Information Technology Tools for Assessment and Prediction of the Potential Effects of Military Noise on Marine Mammals; CS-1082

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. David Helweg; U.S. Navy Space and Naval Warfare Systems Center – San Diego, CA

FY 2000 COMPLETED PROJECT

DESCRIPTION: As concern increases over the expanded presence of man-made sounds in the oceans (e.g., ship traffic sonar and ship shock trials), there is limited information on their effects on marine mammals. Actual sound frequency-intensity combinations are suspected of causing damage to the hearing of marine mammals. The objectives of this project were (1) to provide information that can guide the assessment and prediction of military noise effects on marine mammals, and (2) to develop a methodology to predict the occurrence and distribution of whales in the Southern California region.

This project was comprised of three complementary research efforts. Task 1 was a study comparing the evidence for normal versus pathological changes of marine mammal ear anatomy. Task 2 utilized state-of-the-art knowledge about baleen whale ears to motivate a computational model of baleen whale hearing ability ("WhalEar"). This task was linked closely with anatomical analyses produced by Task 1, because development of the model depends on the state of the knowledge about marine mammal ear anatomy. Task 3 utilized Navy SOund SUrveillance System assets (SOSUS) to study the movement patterns of large whales in the wild. The objective was to automate the use of the U.S. Navy's Integrated Undersea Surveillance System (IUSS) for identifying "hotspots" (seasonal and/or geographic peaks in the abundance of whales in Southern California waters.

BENEFIT: DoD lacks scientifically defensible positions concerning the safe use of low frequency acoustic sonar and ship shock testing in the presence of marine mammals. This effort responded directly to the DoD capability to comply with the National Environmental Policy Act requirements and will contribute directly to answering the National Research Council's Research Needs related to the effect of low-frequency sound on marine mammals.

ACCOMPLISHMENTS: Information on the cetacean sensory processes, performance, and mysticete (baleen whale) auditory morphology was obtained based on otopathological analyses of baleen whale ears. These results have provided the first detailed analyses of baleen whale ears, the first models of baleen whale auditory sensitivity ("WhalEar"), and application of the model to prediction of sensitivity of baleen whales to Department of Defense (DoD) sound types.

The Smart Whale Acoustic Monitoring (SWAM) system was developed to automate the detection and classification of selected whale vocalizations using IUSS Imaging assets. Automated classification can be systematically explored using a complement of nonlinear dynamic classifier algorithms and philosophies (such as Adaptive Resonance Theory networks, dynamic time warping, matched, and replicate filters). The comparative utility of each classification algorithm was benchmarked using a standardized database of whale vocalizations in SOSUS format. With beamforming, the time and location from which whale calls are recorded increased the precision by permitting spatial separation of multiple calling whales. The SWAM implementation of smart triggering, coupled with a well-conceived statistical sampling regime, was benchmarked using blind mapping of the probability distribution for fin and blue whales within the SOCAL sensor range of the San Nicholas Island assets in competition with expert human performance. "WhalEar" results were integrated into the signal processing modules.

TRANSITION: Auditory morphology and WhalEar model results will be used by the basic research community (e.g., bioacoustics, comparative anatomy), applied research community (e.g., auditory modeling), and environmental compliance community (e.g., programs related to NEPA/MMPA compliance). Further work is needed on the WhalEar model to make the model more "scalable" across different species and to integrate the model with other aspects of risk assessment, such as sound field modeling. Some recent events in the Caribbean have focused on developing accurate models of marine mammal auditory risk assessment. The results of the WhalEar modeling can be transferred to new start research on beaked whales. Information on whale occurrence is being transferred to the Pt. Mugu Naval Air Weapons System Range Environmental Impact Statement program and is slated to feed into the Space and Naval Warfare System (San Diego) "Living Marine Resource Risk Assessment" program. The broad objective is to transition information about the effects of DoD sound types on marine mammal auditory anatomy to predictive models and mitigation tools.

PROJECT SUMMARY

PROJECT TITLE & ID: Assessment of Training Noise Impacts on the Red-Cockaded Woodpecker; CS-1083

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Larry Pater; U.S. Army Corps of Engineers Engineer Research and Development Center, Construction Engineering Research Laboratory – Champaign, IL

FY 2001 FUNDS: $200K

DESCRIPTION: This project is addressing the impact of training noises on the endangered red-cockaded woodpecker (RCW), and developing cost-effective techniques to evaluate and monitor effects of military noise on animal species. These techniques include the capability to characterize noise stimuli, document physiological and behavioral responses, and determine resulting population effects due to military noise. The approach assumes that proximate effects can be linked to individual fitness, which in turn can be linked to population effects. The proximate response is measured by observing the number of bird, flushing from the nest cavity and feeding behavior (non-nesting). Field studies of the in-situ response of the animal to the measured noise events will be used to determine dose-response relationships. Individual fitness measurements will include: number of young fledged per nest, adult turnover, group size, and mating success. These demographic parameters will be correlated with measured noise levels. Another noise assessment being considered involves correlating historic demographic data with estimated noise levels, using available training noise models. Four noise types are considered: artillery noise, small arms noise, helicopter noise, and maneuver noise. (i.e., combination of artillery, small arms, and helicopters.)

BENEFIT: This research will provide information required to assess and manage risk to military training capability, the endangered RCW, and other threatened and endangered species (TES). This project will also provide a basis for mitigation and management protocols and guidelines. This will help to alleviate impacts on training capability, avoid the need to acquire additional training land, and minimize litigation and delays.

ACCOMPLISHMENTS: Using the techniques developed in previous years, additional data were gathered to provide statistical power and information regarding yearly variability. The emphasis was placed upon the most severe noise that occurs during maneuver training (machine gun blanks and artillery simulators). These types of noise are the most pervasive across the landscape and emerged as the greatest concern to the U.S. Fish and Wildlife Service. Over three thousand hours of video surveillance tapes were obtained at twenty-four disturbed and undisturbed sites. These involved several live fire ranges, including large caliber downrange locations that were not studied in previous years. Data collected from these sites substantially augments the existing data especially for large caliber fire at close proximity to the source of the noise. Correlation of noise level with RCW productivity was completed using noise contours generated by the BNOISE and SARNAM noise models and training data supplied by Ft. Stewart Audiograms for the Downy woodpecker, a closely related surrogate for the RCW, were completed. Analysis of the noise response data for the FY00 nesting season is currently underway.

TRANSITION: The empirical data from these efforts will be integrated into leveraged RCW population models to assess noise impacts at the population level. Research results will transition into existing land management decision support tools (e.g., management guidelines for testing and training, and the first audiogram for RCW). Additionally, the results will direct the development of management protocols designed to minimize the impacts to endangered species population from noise generated by military activity.

PROJECT SUMMARY

PROJECT TITLE & ID: Error and Uncertainty Analysis for Ecological Modeling and Simulation; CS-1096

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. George Gertner; University of Illinois – Champaign, IL

FY 2001 FUNDS: $387K

DESCRIPTION: With the growing importance of simulation modeling in natural and cultural resource assessment and management, the Department of Defense (DoD) recognized the need for a comprehensive framework to analyze uncertainty of simulation results. These results are based on estimates of the true parameters and, consequently, are associated with a specific degree of uncertainty. Error budgets can be used to assess the quality of the overall simulation system. Although progress has been made in the areas of uncertainty analysis and error budgets, there is a need to develop the statistical and computational tools to enable model users to jointly assess and quantify the sources and magnitude of errors. These errors are associated with large-scale DoD simulation models used for resource assessment and management. The objective is to develop the methodology for formulating error budgets for environmental monitoring-modeling systems. This project provides the rationale to account for the effect of different sources of error on the uncertainty of model predictions, and the rationale for efficiently reducing that uncertainty. This effort focused on six factors of the Revised Universal Soil Loss Equation: (1) rainfall-runoff erosivity factor and climate, (2) soil erodibility factor, (3) slope length factor, (4) slope steepness factor, (5) cover management factor, (6) support practice factor. Error associated with the data, data processing and classification was examined for each of these factors. Modeling error was examined for the Terrain Modeling and Soil Erosion Simulation module of ATTACC and the spatical/distribution of disturbance model due to military activities.

The approach is to develop an analytical framework and a user-friendly interactive software package to assess and exert control over the quality of the simulation results. This project applies this methodology to a monitoring-modeling system [i.e., Army Training and Testing Area Carrying Capacity (ATTACC)] employed by the military for assessment and/or management of natural and cultural resources. The ATTACC model uses a spatially explicit version of the Revised Universal Soil Loss Equation (RUSLE). The RUSLE consists of six factors: rainfall-runoff erosivity factor and climate R, soil erodibility factor K, slope length factor L, slope steepness factor S, cover management factor C, and support practice factor P. The project develops a GIS-based methodology to make spatial and temporal predictions, analyze uncertainty, and build error budgets of soil erosion status based on and applied to military training

BENEFIT: This project will aid DoD's need to develop a comprehensive framework for quantifying, analyzing and managing uncertainty of modeling and simulation results. Additionally, the project will support general ecological and environmental modeling efforts in the other services.

ACCOMPLISHMENTS: Depending on the structure of the subcomponent models and the characteristics of errors for the error budgets, either a deterministic or stochastic approach was developed. The deterministic approaches are based on analytical statistical estimators (expected mean square error models) and Taylor series approximations based on subcomponent models that are mathematically differentiable. The stochastic approaches are Monte Carlo techniques based on simple random and Latin Hypercube sampling, and on Fourier analyses techniques [Fourier amplitude sensitivity test (FAST)]. Hybrid of both approaches based on surrogate models are being developed as well. The surrogate models are a simplification of the overall system and provide a more computationally efficient and statistically assessable means for analysis. These models are the basis for composite error variances and the partitioning of the error variances. The uncertainty software that was developed is more comprehensive (e.g., different variance partitioning methods) and portable in terms of the information input, random number generation, uncertainty analysis for a spatial operation unit, uncertainty analysis for population, and information output.

The uncertainty analysis software that was developed was used to generate the error budgets for the ATTACC model application study at Fort Hood. Various types of budgets were completed.

TRANSITION: This capability will provide the necessary quality control/assurance mechanisms to support DoD decision support systems regarding natural and cultural resources. This methodology will be relevant to all users of ecological and environmental models. Specifically, the uncertainty software developed in the project will likely be incorporated into Land Management System (LMS). However, the project will support general ecological and environmental modeling efforts in the other services as well. This research team has also met with the OO-IDLAMS team discuss incorporation of their results into OO-IDLAMS.

PROJECT SUMMARY

PROJECT TITLE & ID: Ecological Modeling and Simulation Using Error and Uncertainty Analysis; CS-1097

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Anthony King; Oak Ridge National Laboratory – Oak Ridge, TN

FY 2001 FUNDS: $200K

DESCRIPTION: Ecological models are often used in conjunction with a geographical information system (GIS). This project is: (1) identifying and evaluating methods for quantifying uncertainty in spatial data for ecological models; (2) incorporating Monte Carlo analysis into a framework for uncertainty and error analysis of spatial data in ecological models; and (3) testing and demonstrating the Monte Carlo framework and tools with a case study.

The general technical approach is to account for the sources and the effect of uncertainty in simulation modeling. The investigation complements the error budget approach and is closely coordinated with SERDP project CS-1096. The Monte Carlo framework is designed as general and modular software to maximize the ease with which alternative ecological models can be incorporated. This approach facilitates application to different installations, ecological models, and applications.

BENEFIT: The methods and tools developed by this project will be directly applicable to ecological models used throughout Department of Defense (DoD) and Strategic Environmental Research and Develop Program (SERDP). Incorporation of these methods and tools into the land-use decision process as part of an overall error budget analysis and through land-management systems like Integrated Dynamic Landscape Analysis and Modeling System (IDLAMS) and Land Management System (LMS) will directly benefit the DoD conservation practices and the DoD land-use decision process. The general concepts, methods, and tools resulting from this project will also be available to conservation and land-use decisions on private and public lands managed by other agencies, wherever spatially explicit ecological models are used as part of the decision process.

ACCOMPLISHMENTS: During FY 2000, case studies were completed and documented at Fort Knox to support the Henslow's sparrow ecological model and at Fort Hood to support the golden-cheeked warbler ecological model. This involved the review of methods and appropriate techniques for incorporating measured uncertainty in spatial data for each of these studies. The techniques selected are designed to propagate error and uncertainty in spatial input data through a model and to analyze the variability (distribution) of model output that occurs as a consequence. The project continues to coordinate with Dr. Gertner on SERDP Project CS1096 to implement techniques for incorporating measured error in spatial data as a source of uncertainty and with Mr. Anderson on SERDP Project CS1102 to evaluate changes in ATTACC that may make it amenable to incorporating spatial uncertainty methods.

TRANSITION: These methods and tools will be incorporated into land-use decision processes as part of an overall error budget analysis, and as part of land-management decision support systems such as the IDLAMS and LMS. The project has coordinated extensively with other SERDP projects (e.g., CS-1055, CS-1100, CS-1102) to apply the methods of spatial uncertainty analysis to their respective modeling activities.

PROJECT SUMMARY

PROJECT TITLE & ID: Emerging and Contemporary Technologies in Remote Sensing for Ecosystem Assessment and Change Detection on Military Reservations; CS-1098

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Randall Karalus; U.S. Army Corps of Engineers Engineer Research and Development Center, Topographic Engineering Center – Alexandria, VA

FY 2001 FUNDS: $690K

DESCRIPTION: Federal land managers need accurate and affordable ways to assess the health and availability of their training lands. This research is designed to develop techniques that relate ecological concepts of carrying capacity, vegetation dynamics, critical thresholds, habitat fragmentation, ecosystem response and recovery, and land degradation to the response of remotely sensed spectral indicators, and ultimately, to training and testing upon military installations. The objective is to apply spatial and temporal change detection methods over a range of geographic scales using contemporary and emerging remote sensing technologies and traditional field surveys to identify and monitor land degradation.

The approach for this project is essentially a composite of: (1) mapping the installation or selected components thereof; (2) correlating the fundamental attributes of disturbance, vegetative cover, and plant succession; (3) analyzing, retrospectively, the ecological history of each installation in relation to land use; and (4) assessing high resolution systems to identify the sensor attributes necessary to monitor changes in plant species composition along disturbance gradients and plant succession stages.

Two types of analyses will be conducted: retrospective analysis, and ecotone and degradation gradient analysis. The purpose is to consider ecosystems in terms of their temporal and spatial characteristics, respectively. The retrospective analysis is a combination of (1), (2), and (3) described above. Whereas, the ecotone and degradation analysis is a combination of (1), (2), and (4). Analyses will be conducted at three facilities: Camp Williams, Utah - Army National Guard; Fort Bliss, Texas - U.S. Army; and, Marine Corps Air Ground Combat Center (MCAGCC), Twentynine Palms, California. Each of these facilities represents three of the four types of desert ecosystems in the U.S.: the Intermountain Cold Desert, Chihuahuan Desert, and Mojave Desert.

BENEFIT: Installation managers will benefit from standard techniques for cost-effective environmental change detection and extrapolation of field data through the use of remotely sensed data. The capabilities produced by this research will significantly improve the accuracy and cost/time-effectiveness of data collection, monitoring, and modeling for military land management.

ACCOMPLISHMENTS: Data acquisition efforts included: ground data at Camp Williams and MCAGCC, hyperspectral imagery, limited IKONOS imagery, Landsat imagery with associated metadata, and CAMIS and Kodak imagery. The georeferencing, orthorectification, and mosaicking of all CAMIS and Kodak imagery is completed. CDs have been produced to facilitate data sharing. Since the completion of the georeferencing, image classifications and ecological interpretations have been initiated using various classifiers. Vegetation polygons created from ground data were digitized onto the georeferencd mosaics for most of the study sites. These polygons have been used to test the accuracy of the classifications. A vegetation analysis was conducted to determine how certain vegetation species and/or species groups are related to site degradation. The species that are indicators of degradation were identified and now efforts are being made to determine if their spectral characteristics can be identified using image processing techniques. As part of conducting the scaling analysis, a program was revised to provide the ability to drop a grid of user specified grid resolution on top a higher resolution data set. This program is central to both demixing and regression analysis. The retrospective analysis component of this project continues to focus on the radiometric and geometric standardization of the imagery collected for Ft. Bliss, Camp Williams, and MCAGCC. Land use and ecological histories (RFMSS data) for each installation have been collected to help derive the ecological history of each installation in relation to land use and ultimately correlate historic remotely-sensed spectral variations of land cover with land use.

TRANSITION: The project will acquire an impressive, and to a large degree unprecedented, array of imagery data types for three military facilities (National Guard, U.S. Army, and U.S. Marine Corps). University of Nevada - Reno (UNR) constructed a web site (http://www.ag.unr.edu/serdp) to facilitate data transfer. The website will be integrated with University of Illinois at Urbana and Utah State University's websites this year. The data will provide a baseline against which installation managers can compare future inventories and interventions. This database will not only be available for the installation managers and their environmental staff, but will also be available for further research and adaptation by other research organizations. Deliverables include: models for change detection of land use on military reservations; methods for scale transitions; relationships between hierarchical scheme of spectral and spatial resolution to ecotone/biological thresholds/degradation; protocols for data extrapolation from remote sensing imagery; and a better understanding of ecosystem response and recovery in relation to disturbance (land use).

PROJECT SUMMARY

PROJECT TITLE & ID: Predicting the Effects of Ecosystem Fragmentation and Restoration: Management Models for Animal Populations; CS-1100

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Thomas Sisk; Northern Arizona University – Flagstaff, AZ

FY 2001 FUNDS: $175K

DESCRIPTION: DoD training and related activities on and adjacent to military lands often contribute to fragmentation and affect species of special concern, including threatened and endangered species. This project proposes to develop species-specific models that predict the responses of mobile animal species in heterogeneous landscapes. Modeling efforts will build on connections between life history characteristics and the responses of mobile animals to habitat fragmentation and restoration. Field research will permit parameterization of models and testing of model predictions, leading to refinement of the conceptual approach. The primary foci are the ponderosa pine forests and riparian habitats on military lands. These two habitat types are widespread throughout the U.S. and currently the subject of great management debate.

This project is a cooperative effort involving Northern Arizona University, Colorado State University, the Ponderosa Pine Ecosystem Restoration Project, the Semi-Arid Land Surface Atmosphere (SALSA) Project, Camp Navajo (U.S. Army and Arizona Army National Guard), and Ft. Huachuca (U.S. Army). There are three areas of investigation being conducted: (1) acquisition of ecological field data on the responses of animals to habitat fragmentation; (2) the mapping of animal habitats in three dimensions and at scales relevant to habitat management; and (3) the linking of empirical ecological data and spatially explicit habitat information in a management-oriented effective area model (EAM). Habitat mapping will rely on remotely-sensed data and field measurements. Land Remote-Sensing Satellite (LANDSAT) imagery and aerial photography will permit delineation of the spatial extent, shape, and juxtaposition of habitat patches. Important structural attributes will be explored through the use of Synthetic Aperture Radar, aerial photography, and field measurements. Overlay of pertinent data sets in a Geographical Information System environment will allow integration of habitat attributes and identification of floristically and structurally distinct habitat types, as well as the edges that separate different habitat patches. Completed habitat maps will serve as input to the EAM.

BENEFIT: The project will link field and remotely sensed data in validated landscape models that will permit comparison of alternative land use strategies on wildlife species of management concern. The model operates in the ARC and ArcView geographic information system environments. Through manipulation of habitat maps, the EAM will be capable of predicting the effects of alternative landscape modifications -- habitat fragmentation due to operational activities, or habitat restoration resulting from rehabilitation or mitigation efforts -- on a wide range of animal species.

ACCOMPLISHMENTS: During FY00, this project progressed on four major fronts. (1) The development of the Effective Area Model reached an important milestone when it became fully operational in the Arc View environment and moved toward beta release. (2) Field studies advanced understanding of animal responses to habitat edges, improving model parameterization and therefore, density estimates. (3) Field work also collected data from independent model test sites, permitting evaluation of first-generation tests of EAM output. (4) The impacts of landscape fragmentation on animal fitness for both birds and butterflies, in both desert riparian woodlands and ponderosa pine forests was initiated.

TRANSITION: The project results will be provided to land managers who will link field and remotely sensed data in validated landscape models that will permit comparison of alternative land use strategies on wildlife species of management concern. Extensive field testing of model predictions in different environments will permit evaluations of model effectiveness in forecasting the responses of a wide range of species to landscape-scale alterations in forested and riparian habitats.

PROJECT SUMMARY

PROJECT TITLE & ID: Improved Units of Measure for Training and Testing Area Carrying Capacity Estimation; CS-1102

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Alan Anderson; U.S. Army Corps of Engineers Engineer Research and Development Center, Construction Engineering Research Laboratory – Champaign, IL

FY 2001 FUNDS: $200K

DESCRIPTION: This project proposes to significantly improve the Army Training and Testing Area Carrying Capacity (ATTACC) methodology as an installation management tool to better predict the environmental consequences of military training activities. The focus of this project is to develop quantitative units of measure (such as erosion and species composition on land) to estimate training and testing land carrying capacity, extend the spatial and temporal scale of the methodology to include individual training areas and changes in training and land condition throughout the year, and validate the improved methodology.

The enhancements that are being incorporated into the ATTACC model include: (1) revised water erosion model; (2) wind erosion model; (3) plant species composition; and (4) time varying climatic factors. The unit stream power approach for estimating the topographic factor of Revised Universal Soil Loss Equation (RUSLE) will be incorporated into the water erosion model to account for complex topography typical of military lands. Existing wind erosion models will be evaluated to determine which is the most applicable to military lands based on data requirements and model assumptions. The results from the completed SERDP project on Terrain Modeling and Soil Erosion (CS-752), are being used to improve estimates of land condition and can be extended to off-site impacts (sedimentation and water quality). To incorporate species composition into the ATTACC model, the Ecological Dynamics Simulation (EDYS) model, (i.e., a process-based model that predicts changes in species composition that naturally occur over time and in response to natural disturbances) will be utilized. A sub-model will be developed for the EDYS model, that translates training/testing activities into changes in soil and vegetation processes. Existing DoD impact studies are used to estimate the primary impacts of military activities on soil and vegetation processes. Components of the ATTACC model will be modified to incorporate time varying climatic factors.

BENEFIT: By providing an improved methodology, mission impacts can more accurately be matched to the ecological capability of military lands to support those activities resulting in decreased land maintenance costs, maintaining realistic training conditions, and increasing land use capacities.

ACCOMPLISHMENTS: The unit stream power approach for estimating the topographic factor of RUSLE has been incorporated into the ATTACC model. Progress has been made on incorporating wind erosion into the ATTACC model. A wind erosion model has been selected. The evaluation process, results, and model limitations are being documented. A military impact component of the EDYS model was developed. The software allows the EDYS model to predict changes in plant species composition associated with military activity. Currently the interface between training/testing distribution patterns and the military impact component of EDYS is being developed. This interface will allow training and testing activities as defined in ATTACC to be incorporated into the EDYS model to predict long-term changes in species composition associated with mission scenarios. Field validation of the model has been completed.

Improvements have been made to the spatial/temporal scale of the ATTACC model. Improved training impact factors were developed for the ATTACC model that accounts for seasonal variation in mission impacts. Improved Vehicle Severity Factors (VSF) are being developed that more accurately account for the impacts of different types of vehicles. Improved Local Condition Factors (LCF) are also being developed that account for differences in soil moisture on mission impacts.

TRANSITION: Researchers are actively involved in the Army Corps of Engineers' Land Management System (LMS) initiative and are currently participating in the Fort Hood LMS Military Demonstration and activities of the LMS Integration Team. Project activities are coordinated with several DoD user groups including (1) the ATTACC Wind Erosion Advisory Group, (2) ITAM Installation Steering Committee, and (3) ATTACC Working Group. Team members have also been asked to serve on the United States Department of Agriculture (USDA) WEPS advisory group.

PROJECT SUMMARY

PROJECT TITLE & ID: Identify Resilient Plant Characteristics and Develop a Wear Resistant Plant Cultivar for Use on Military Training Lands; CS-1103

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Antonio Palazzo; U.S. Army Corps of Engineers Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory – Hanover, NH

FY 2001 FUNDS: $300K

DESCRIPTION: Wear-resistant plants are needed to mitigate environmental impacts and improve the use of Department of Defense (DoD) training lands. Knowledge of the relationships between military training and plant injury, regrowth, and wear resistance is limited. Plant and soil data will be combined allowing land users to make knowledgeable choices concerning plant selection and site-rehabilitation procedures to reduce soil erosion. This project intends to use several collections of resilient and other plants to breed new more resilient cultivars. A second objective is to conduct field and greenhouse studies to quantify the degree of compaction that occurs during training and relate soil condition to root injury in plants with known resilience.

The technical approach identifies and develops training-resilient plant cultivars. Field and greenhouse studies will be conducted to quantify the degree of soil compaction that occurs during training, relating this soil condition to root injury in plants with known resilience. The greenhouse study is on soil compaction and plant root growth. Three species are being studied (Reliant hard fescue, Blackwell switchgrass, and western wheatgrass) and three compaction levels in six soils. The field study is evaluating a naturalized cultivar (‘Vavilov’ Siberian wheatgrass, *Agropyron fragile*) and two native cultivars (Goldar bluebunch wheatgrass, *Pseudoroegneria* spicata and ‘Secar’ Snake River wheatgrass, *Elymus wawawaiensis*) which were seeded in mixtures and in several different row-space combinations to determine if rapidly establishing naturalized and native species can be established together.

BENEFIT: This project will provide DoD guidance for mitigation methods in restoring training lands and will provide more resilient plant species that will help to increase training opportunities on existing training areas. This guidance will assist land managers and trainers in making choices on training schedules and in estimating cost and time requirements for maintaining military readiness.

ACCOMPLISHMENTS: A recurrent selection program in populations of the native and naturalized species continued as part of the plant breeding effort. Seed increase procedures were initiated with three experimental populations. Progeny lines from other breeding populations were established in evaluation nurseries, from which selections were made to form the parentage of new germplasms. Breeding and evaluation studies focused on stand-establishment vigor, rate of tillering and rhizome development, vegetative vigor, and seed-yield potential. Native grasses with seed dormancy problems, such as western wheatgrass and Great Basin wildrye, were screened for more rapid germination. The tracking study at YTC was completed and results show that tank tracking had very little effect on soil compaction below 10 cm on the dry soils at this location; however native and introduced grasses differed in their responses to disturbances associated with tank traffic. A greenhouse study on the effects of soil compaction on root growth was completed and the results are being analyzed.

TRANSITION: The results and findings of this project can be expanded to include the development and testing of additional plant species on a variety of soil types. This will provide opportunities for widespread application/demonstrations of this information to other testing and training ranges. This project will provide valuable information for organizations outside of DoD who deal with plant resiliency and soil compaction problems, as well.

PROJECT SUMMARY

PROJECT TITLE & ID: SERDP Ecosystem Management Program (SEMP); CS-1114

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. William Goran; U.S. Army Corps of Engineers Engineer Research and Development Center, Construction Engineering Research Laboratory – Champaign, IL

FY 2001 FUNDS: $2526K

DESCRIPTION: The SERDP Environmental Monitoring Program (SEMP) was established as an outgrowth of the 1997 SERDP Management Scale Ecological Research Workshop during which it was determined that the DoD should establish a long-term ecological monitoring program at a military base with possible expansion to some other bases in the future. The overall program objective of SEMP is three-fold. First, SEMP directs and selects DoD relevant, ecosystem management research initiatives. Secondly, it manages a long-term ecological monitoring system(s) to support these research efforts while also fulfilling some of the host installations monitoring requirements. Finally, SEMP facilitates the integration of results and findings of research into DoD ecosystem management practices. The SEMP is managed by a separate Program Manager with the assistance of a Technical Advisory Committee (TAC).

Under the Ecosystem Characterization and Monitoring Initiative (ECMI), a team works with the host installation to gather, assess and document historic and current ecological data sources and monitoring efforts. In addition, this team is responsible for long term ecological monitoring. Data from the characterization effort, the monitoring efforts and the research teams all flows into the common data repository, shared by all research teams and the installation managers.

Selected research teams work in a collaborative context -- sharing field sites and approaches, entering data into a common repository, reviewing each other's findings, and contributing to common technology transfer mechanisms. Three research groups were initiated in FY99 to examine ecological indicators. The objectives are (1) to identify indicators of ecological change at multiple spatial and temporal scales, and (2) to establish relationships between ecological indicators and land use. In FY00, two research teams initiated the identification of ecological disturbance from military land use with the objective being to develop the knowledge to implement ecosystem management approaches for military lands.

BENEFIT: DoD's Conservation user community is directed to implement an ecosystem approach to land management issues. However, there is a critical need for scientific information to support this approach, especially as it relates to integrating ecosystem management with mission concerns. The success of user plans will depend on the capabilities and increased knowledge generated by research investment. SEMP will facilitate a number of studies that can be sufficiently planned and funded to allow a full array of remote sensing, ground truth experiments, modeling, cause-effect studies, etc. to be integrated to address complex problems. This contributes to data sharing, leveraging, and joint publications, supported by major experimental findings. Focused development of an ecosystem research plan, appropriate instrumentation and monitoring to support this research, and identification and selection of the most effective, technically sound research efforts to answer user needs will all contribute to the science and understanding necessary for an ecosystem approach to land management.

ACCOMPLISHMENTS: In FY00, representatives from the SEMP teams and outside organizations discussed the integration of findings/results generated by the baseline monitoring and individual research projects into a conceptual framework that would serve to demonstrate the intent and purpose of SEMP. This effort provided the structure to assist in the planning of future solicitations and management direction under SEMP. SEMP continues to pursue technology transfer opportunities with presentations and displays at the SERDP Annual Symposium and the Ecological Society of American Meeting.

Under ECMI, an Executive Summary of the long-term monitoring program design was completed and was approved by Ft. Benning staff , and the SEMP TAC. A reconnaissance field trip was conducted to identify sites for aquatic (surface water and groundwater) monitoring. A surface water monitoring site was installed on Upatoi Creek and a low flow sensor on Wolf Creek. A data repository was developed and existing data were bulk loaded into the repository. A master research site location map was constructed to identify the individual studies sites for each research team which will be linked to (1) existing GIS layers being used by the installation, and (2) metadata in the data repository.

Three research teams initiated their investigation in FY99 to identify ecological indicators. A University of Florida team is testing the hypothesis that indicators of soil and hydrology (surface and subsurface) can be used to identify storage processes that point to a specific ecosystem condition and that the change in soil water flow and storage reflect the degree of disturbance. Another FY99 team, being led by CERL, is exploring unique indicators of stress within an ecosystem functional systems or guilds. They are testing ten ecological indicator systems. An ORNL team effort is identifying a suite of indicators within the understory, soil biomass and aquatic environments that transect both spatial and temporal scales across a disturbance gradient. In FY00, these three research teams collected at least one year of sampling data (i.e., data include: watershed hydrology, soil hydrologic properties, soil biochemical properties, developmental instability and plant physiology, terrestrial invertebrates, fish, nutrient flux in soil, soil bacteria and fungal diversity, vegetative species identification, stream chemistry, benthic invertebrates, historic vegetation) and initiated preliminary analyses of these data. The ORNL team also investigated the historical trends affecting candidate indicators by extracting data from historical documents and maps and converting them to a digital format for analysis.

Two additional teams, examining disturbance regimes and ecological thresholds, began in FY00. A Savannah River Ecology Laboratory Team is testing the hypotheses that soil type influences the nutrient cycling, diversity, vegetation and threshold for land use. The second team, led by ORNL, is measuring soil quality parameters along a disturbance gradient to determine if these parameters change in a detectable and meaningful manner. These two teams began their efforts by selecting studies sites, initiating sampling efforts, conducting baseline vegetation survey and analyzing some of the existing soil samples collected by one of the FY99 teams. Monitoring transects and points were established for these teams also.

A website was established for SEMP under the Defense Environmental Network Information eXchange (DENIX) working group area. This website includes a calendar of activities, linkages to other sites, selected SEMP briefings and publications for review and for downloading, and a discussion forum. The URL for this website is http://www.denix.osd.mil/SEMP. SEMP continues to pursue technology transfer opportunities with presentations and displays at the SERDP Annual Symposium and the Ecological Society of America Meeting.

TRANSITION: The goal of SEMP is to provide knowledge, tools, and techniques to contribute to understanding and enhancement of the ecological role of military installations within their ecoregions. Project results and findings will be integrated into DoD ecosystem management policy and procedures to provide DoD land managers the necessary guidance and tools for a sustaining future military training and testing. The monitoring and research results will also be available to other Federal land managers.

PROJECT SUMMARY

PROJECT TITLE & ID: Dynamic Modeling of Military Training Impacts and Archaeological Site Distributions in Evolving Landscapes; CS-1130

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. James Zeidler; Colorado State University – Fort Collins, CO

FY 2000 COMPLETED PROJECT

DESCRIPTION: This "proof-of-principle" study addresses the ability to effectively model and predict the distribution of archaeological (including prehistoric, historic, and traditional cultural property) resources on military and Department of Energy (DOE) lands and ranges, and address the potential or probability of unique impacts that adversely affect those resources. It was aimed at demonstrating (1) the effectiveness of a 3-D computer simulation approach to predictive archaeological modeling and resource risk assessment, and (2) transferability of the approach to other installations. The 3-D modeling incorporated the Channel-Hillslope Integrated Landscape Development (CHILD) model which provides a quantitative geomorphic context for interpreting the space/time correlations among archaeological materials in the alluvial basin by simulating the processes of dispersal by erosion and burial by deposition. Interpretation and validation of simulation results were carried out using existing empirical geomorphological data from extensive subsurface geoarchaeological testing (e.g., profile cutting, backhoeing, coring, etc.) at Fort Riley. 3-D "archaeological sensitivity" maps were compared with the existing 2-D predictive model of the same drainage for an evaluation of relative predictive accuracy and ultimate utility for land management purposes.

BENEFIT: The model provides a powerful tool for visualizing the dynamic nature of landforms to help. predict the prehistoric human activities and settlement locations and reconstruct the spatial extent of archaeologically important sediment features, such as paleosols.

ACCOMPLISHMENTS: A 3-dimension approach using the known archaeological record, historical military training activities, and the CHILD Model was developed. This integrated geomorphic modeling of archaeological site location and training impacts provides a predictive tool to identify the probability of finding buried resources and the degree to which these resource are at risk from military activities. The resulting 3-D model produced "archaeological sensitivity" maps. These maps were compared with a 2-D model of the same basin. The results indicate that the 2-D approach to predictive modeling is deficient for detecting buried archaeological sites, and is even misleading, in some cases, at providing reliable probabilities of archaeological site potential for particular landforms and paleosols. In addition to the modeling comparison study, the minimal amount of empirical paleoenvironmental and geomorphological data (i.e., sampling intensity) that is required to both calibrate the simulation exercises and validate the results was determined to qualify transfer of the methodology to other installations.

TRANSITION: Transferability of this approach to other installations and landscapes will be examined in terms of an evaluation of the minimal paleoenvironmental and geoarchaeological data requirements for successfully calibrating and validating the simulation exercises.

PROJECT SUMMARY

PROJECT TITLE & ID: Diagnostic Tools and Reclamation Technology for Mitigation Impacts of DoD/DOE Activities on Arid Areas; CS-1131

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. W. Kent Ostler; Bechtel Nevada – Las Vegas, NV

FY 2001 FUNDS: $415K

DESCRIPTION: This project is designed to overcome current gaps in diagnostic capabilities needed to distinguish between various degrees of sustainable and non-sustainable impacts due to military training and testing activities in desert ecosystems. Additionally, the project aims to develop and evaluate new and cost-effective techniques for rehabilitation and restoration of such disturbed habitats.

The technologies being evaluated and tested are divided into two principal areas: diagnostics and restoration techniques. For diagnostic techniques, new rapid detection methods will be developed using hand-held digital cameras and Hi-8 camcorders to record selected ground data such as panoramic views with vertical and horizontal scale references to record shrub height and canopy width, regularly-spaced closeups to document shrub sprouts, percentage of live shrubs, emergence of seedlings, and morphological demographic data (approximate proportion of shrubs at different ages or sizes). Combinations of innovative revegetation techniques developed at sites in the Mojave Desert will be applied to disturbed lands at Fort Irwin. The approach includes the establishment of plots of land representing 5 to 10 classes or degrees of disturbance ranging from light disturbance to very heavily disturbed sites (non-vegetated). Plots will be treated at Fort Irwin with revegetation techniques. Vegetation and site conditions will be documented in representative areas for each degree of disturbance. Ground data from the sites will be correlated with remote sensing data. Field data will be taken over a four-year period by the proposed image collection techniques previously described.

BENEFIT: Approximately 70% of all U.S. military training lands are located in arid areas that will benefit directly from these technologies. Under current technology, it is estimated that up to 35% of revegetation projects will fail. Applying the results of this project will increase the success of the restoration and possibly save DoD as much as $5 million annually. These diagnostic tools will enable management to maximize utilization of limited training environs and thus increase operational readiness.

ACCOMPLISHMENTS: New image collection techniques were investigated. Different methods for rapid collection of data and images including the most effective scales for interpreting vegetation impacts or changes were investigated at Ft. Irwin and other sites with differing vegetation communities. Data needs for DoD models particularly the ATTACC model were identified and evaluated. Two sets of high-resolution imagery at Fort Irwin were acquired, which have helped to evaluate the appropriate scale and photo equipment necessary to obtain usable imagery. Satellite data have been compared to aerial photographs in a transect across a major valley at Fort Irwin to assess if disruption data can be correlated between these two techniques. Laser-induced flourescence imagery equipment was used at Fort Irwin to evaluate the dominant species at the site and evaluate seasonal changes in stress levels. Spectral changes of these dominant species when subjected to controlled levels of impact/damage were characterized.

The evaluation and development of image processing software for vegetation assessment continued. A series of test locations at Fort Irwin were established to correlate photographic image analyses with satellite data. Data from the new Landsat Enhanced Thematic Mapper was used to assist in developing these correlations. Multispectral data were evaluated to determine the capability of the data to assess vegetation differences and impacts from training.

Five study areas with varying soil types and levels of disruption (moderate, heavy, and intense) were selected at Ft. Irwin. These sites were "marked/fenced" and sampled in the spring to assess initial seedling germination and establishment. Several supportive plots were established to support a cost-effective analysis for a variety of restoration techniques.

TRANSITION: Technologies developed by this program can be used for a variety of applications currently needed by government agencies with land management responsibilities in both arid and moist environments. The primary applications include: (1) evaluating and monitoring the site's ability to recover from various levels of impacts, (2) rapidly assessing shrub density, height, diameter, size class and percent canopy cover (important for controlling erosion), and (3) developing cost-effective revegetation techniques. Results from this project will be integrated into land management decision support tools to provide DoD land managers the necessary guidance for mitigation methods that will help to increase training opportunities on existing training areas.

PROJECT SUMMARY

PROJECT TITLE & ID: Application of Hyperspectral Techniques to Monitoring & Management of Invasive Weed Infestation; CS-1143

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Susan Ustin; University of California – Davis, CA

FY 2001 FUNDS: $258K

DESCRIPTION: The rapid spread of non-native invasive plant species, including noxious weeds is causing irreparable damage to the natural resources on military installations. This project aims to develop and demonstrate a new remote sensing methodology using hyperspectral imaging (HSI), for mapping invasive weeds. Seven bases have been selected that have different weed types, intensities, and patterns of environmental disturbances from the southeast, southwest, and northwest ecoregions of the U.S. to demonstrate, refine and validate the proposed methodology. These case studies will demonstrate the portability of the methods under conditions of different types of military activities. Wall-to-wall maps will not be developed. Instead, appropriate airborne flightlines that include a range of types of weed problems on the base, intensity of invasive weeds, and encompass a range of land use conditions will be identified. These data will provide a basis for demonstrating and assessing the benefits of HSI data for mapping various species of weeds under the diverse conditions existing at each of these military bases.

New support vector machine learning tools will be used to characterize the habitats and identify weeds in the HSI imagery. The Hierarchical Foreground Background Analysis (HFBA) is one example of a multi-scale resolution analysis that is used to link the spectral variation for each pixel with variation in the spatial domain. The HFBA decomposition is coupled with a wavelet-based, multi-scale resolution in the spatial domain. This method addresses three issues regarding spectral features which are not addressed by standard methods of image analysis that focus on each pixel separately. Spectral redundancy, the span and completeness of a supervised classification, and a mechanism for producing an automatic classification are the key issues to be addressed. The combination of HSI tools for analysis of field spectra and images will provide a robust protocol for monitoring ecosystems that can be applied, even when the specifics of the location and the nature of the invasive species changes. The tools will be compatible with existing Land Management System (LMS) environmental management models.

BENEFIT: The immediate benefit of this project will be a better understanding of the distribution of major invasive weeds on military bases and the environmental conditions associated with their distributions and spread. The long-term benefit will be in developing a cost-effective method for mapping weeds that can be used to monitor spread of weeds to new locations.

ACCOMPLISHMENTS: In FY00, this project coordinated with base personnel at Vandenberg and Camp Pendleton to access the sites, identify problem weeds, and identify flightlines for remote sensing data acquisition. Field measurements of ecological characteristics and spectral characteristics of habitats and weeds at Vandenberg and Camp Pendleton have been completed. AVIRIS image data was acquired from NASA over Camp Pendleton (Oct. 1999, July 2000 and Sept. 2000), over Vandenberg (September 2000), and Yuma Training Center (July 2000). All data was requested from NASA Jet Propulsion Laboratory. Also in FY00, the project team acquired GIS databases from Vandenberg and Camp Pendleton and established coordination with SERDP investigators and other DoD HSI investigators working at these sites. The project initialized the analysis of field data from the summer.

TRANSITION: Demonstrations of the tools will be provided to site personnel and written technology transfer documents and a web based training course as part of the technology transfer objectives will be developed. The image analysis and other software tools to be developed are compatible with GIS based management protocols and compatible with LMS software.

PROJECT SUMMARY

PROJECT TITLE & ID: Exotic Annual Grasses in Western Rangelands: Predicting Resistance & Resilience of Native Ecosystems Invasion; CS-1144

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jayne Belnap; U.S. Geological Survey, Canyonlands Field Station – Moab, UT

FY 2001 FUNDS: $282K

DESCRIPTION: This project is examining what controls whether a system is susceptible to invasive species. While physical disturbance appears to play a role, many disturbed areas are not invaded, while many undisturbed areas have been invaded. This project proposes to (1) determine if the current distribution of cheatgrass (*Bromus tectorum* - an invasive species) and other annual grasses can be predicted on a landscape and regional level using soil chemistry; (2) construct a model that predicts which soils are resistant or susceptible to annual grass invasion for a large watershed; (3) investigate positive feedback loops that may perpetuate annual grass dominance, such as altered soil organic matter, litter, or chemistry; and (4) examine ways to favor native plant re-invasion by altering soil chemistry.

The initial focus will be the random selection and sampling of sites. These sites will represent major habitat types (based on vegetation and soil types) within the watershed surrounding Virginia Park. At each site, slope, aspect, elevation, soil type, past and present anthropogenic disturbance and distance to roads will be noted. Cover of vascular and non-vascular vegetation will be estimated. Soil depth and stability will be assessed along with chemical properties. Soil food webs will be analyzed as well. Magnetic properties, which indicate the presence of windblown dust, will be measured. Regression analyses will be done to see what factors best predict the presence of *Bromus*. If nothing is found to predict cheatgrass presence, the above will be repeated in an area of winter-rain only.

BENEFIT: This project will aid managers in predicting what soils are susceptible to invasive species and facilitate re-establishment of lost habitat. In addition, understanding how annual grass invasion changes natural ecosystem processes, such as nutrient availability, water availability, and soil microbial systems and how these changes affect re-establishment of native perennial plants, will enhance efforts to restore lost habitat. Specifically, the information resulting from this project will help prevent *Bromus* invasion, and therefore, sustain valuable military training and testing lands.

ACCOMPLISHMENTS: In FY00, this project (1) established the most effective resin products for measuring plant-available nutrients for pot trials; (2) conducted pot trials on *Bromus*, *Hilaria* and *Bromus/Hilaria* mix using a variety of nutrient amendments; (3) evaluated germination, growth and biomass of pot trials; (4) documented the affects of Bromus on soil chemistry and plant communities; (5) began landscape assessment to determine the vegetation and soil chemistry "fingerprint" of habitats vulnerable to invasion; and (6) established field trials in non-invaded soils, applying soil amendments, rodent enclosures, and *Bromus* seed to better understand what keeps these soils from invasion.

TRANSITION: The projects resulting from this project will include datasets, metadata, technical reports, scientific publications and field consultations with land managers. Printed and digital media will be distributed. The project results will have impact on directing the specific management actions relative to *Bromus* invasion.

PROJECT SUMMARY

PROJECT TITLE & ID: Integrated Control & Assessment of Knapweed & Cheatgrass on Department of Defense (DoD) Installations; CS-1145

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mark Paschke; Colorado State University – Fort Collins, CO

FY 2001 FUNDS: $272K

DESCRIPTION: The objective of the project is to develop a strategy for the control, monitoring and prediction of knapweed and cheatgrass infestations at two military installations in the Western U.S. The technical approach evaluates the combined effects of (1) biological control using insect pathogens, (2) fire, (3) manipulation of soil N availability, (4) seeding with native late-seral species, and (5) restoration of the soil community. A replicated partial factorial arrangement of test plots in established communities of cheatgrass and knapweed are being used. The results of these manipulations on plant community composition will be monitored over a four-year period in order to evaluate success. Results from our study will be incorporated into an existing ecological dynamics simulation (EDYS) model. The EDYS model will be calibrated to each of the field study sites to assess the direct and indirect effects of treatments on ecosystem dynamics at multiple spatial scales, and to project potential effects of treatments on long-term successional dynamics. Remote sensing methods will be used to test the effectiveness of these methods for monitoring population densities of weed species over a large area.

BENEFIT: This project will provide be a new effective methodology for controlling non-indigenous invasive plant species. The overall long-term benefit will be reduction of knapweed and cheatgrass populations on military installations and other lands, and a return of native plant communities to provide more realistic training areas and thus improve mission readiness.

ACCOMPLISHMENTS: Research plots were located and established at Yakima Training Center, WA, and Fort Carson, CO. Plot-level baseline (pre-treatment) data has been collected (i.e., plant community biomass composition, soil fungal community assessment, plot-level soil chemistry and nitrogen cycling data, and knapweed biocontrol population assessments). The Department of Energy (DOE) Remote Sensing Lab completed remote sensing of research plots at Yakima Training Center. MSS/GCS data was collected using a BO-105 helicopter with photographic and ground truth support. Biological control agents of knapweeds have been released by USDA-ARS and are being monitored on a continuing basis. Treatments to reduce soil nitrogen availability began in the spring after baseline data collection was completed. The effectiveness of this treatment was monitored throughout the growing season using in-situ, ion-exchange resin (IER) bags. Burn treatments on cheatgrass plots has been successfully completed at Yakima Training Center and Fort Carson. Seeding and soil inoculation treatments were also completed at these two sites.

TRANSITION: Resulting methodology for controlling these weeds will be made available to others by the means of peer-reviewed journal articles, web pages, and presentations at scientific meetings and symposia. The project results will directly serve to facilitate current management actions at military installations.

PROJECT SUMMARY

PROJECT TITLE & ID: Developing Biological Control of Garlic Mustard; CS-1146

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Bernd Blossey; Cornell University – Ithaca, NY

FY 2001 FUNDS: $157K

DESCRIPTION: Garlic mustard (*Alliaria petiolata*) is one of the most serious invasive species in the Northeast, Southeast and Midwest United States replacing native spring wildflowers in forest communities. Physical, mechanical, and chemical means have failed to provide long-term control. The development of biological control appears the only viable option for ecologically sound management of garlic mustard. This project proposes to study ecology, life history and impact of insect herbivores as a biological control for garlic mustard. This project focuses on the development of a standardized long-term monitoring plan to assess the impact of released biocontrol agents on target plant and associated plant communities.

Personnel at CABI Bioscience Center in Switzerland will undertake detailed investigations on the ecology, life history and impact of 5 potential biocontrol agents for garlic mustard in Europe and determine their host specificity. They will provide details of the life history (phenology, competitive interactions, natural enemies) and impact on plant growth and population dynamics by potential biological control agents of garlic mustard. An important focus of the investigations will be to observe changes in plant growth or biomass allocation of garlic mustard in response to different densities of control agents. In addition, the influence on plant performance as a result of attack by single or multiple species (i.e., on above and below ground plant tissues) will be assessed in the field and in common garden experiments. These studies of herbivore interactions will help determine whether the introduction of multiple agents is warranted or should be avoided.

To assess the impact of the release of biocontrol agents on garlic mustard and native plant communities, a standardized monitoring protocol will be developed. Potential field sites will be visited and long-term monitoring sites will be established. Data will be collected on garlic mustard performance (height, seed production) and abundance (presence/absence, number of stems, cover, biomass) at sites in North America (no specific herbivores) and in Europe (with host specific herbivores). Basic site specific parameters (exposure, overstory species, soil types etc.) will be recorded to evaluate the influence of habitat types on the control success. Measures of control agent abundance (and of native insects or pathogens that may occur on garlic mustard) and damage will be recorded in abundance and damage classes. Data collections will occur in spring and fall and the most meaningful parameters will be selected for continuation at the end of the first field season.

BENEFIT: The development and implementation of biological weed control programs, e.g., the introduction of host specific herbivores from the native range of a non-indigenous plant species, offers an ecologically sound, cost-effective, long-term management strategy that will help protect native species and their habitats.

ACCOMPLISHMENTS: In FY00, this project focused on testing the specificity of four promising potential biological control agents. Roots, seeds and tubers of North American test plant species were shipped in early spring and are grown in a common garden in Switzerland. Tests with different species have shown a restriction to the target plant, garlic mustard, for all weevil species. At present, at least all weevil species tested so far appear to be host specific. A large-scale experiment investigating the impact of the two stem mining weevils, *Ceutorhynchus alliariae* and *C. roberti*, was established and completed during the 2000 field season. Additional field surveys located promising study and collection sites for additional work. A preliminary protocol for monitoring garlic mustard and associated forest flora in North America was developed. Permanent monitoring quadrants were established at West Point, NY and Fermilab, IL. These sites will be used to further fine-tune the monitoring protocol before it can be handed out to natural areas managers. Field surveys in North America revealed a number of associated diseases and insects that already attack garlic mustard in North America. At present it is unclear whether these organisms are introduced or native. Reference specimens have been collected and will be sent to specialists to receive a species identification. Among the organisms found were two stem mining weevils (these are different from the ones studied in Europe), a leaf mining fly, 2 polyphagous fungi, a scale insect, a stem mining fly and several parasitoids attacking these herbivores. Over 1,300 plants were harvested, dissected for herbivores and measured for height, reproductive effort, and dry biomass. The project will use these to develop regression equations allowing us to use non-destructive measure (stem height, for example) in the monitoring protocol but estimate overall garlic mustard biomass.

TRANSITION: This protocol will be used by researchers and natural resource managers at military installations and other agencies to monitor the success of control agents after their release in North America. Workshops and manuals will be used to introduce resource managers to the application of biological weed control and in the use of the monitoring protocol.

PROJECT SUMMARY

PROJECT TITLE & ID: Analysis of Desert Shrubs Along First Order Channels on the Desert Piedmonts: Possible Indicators of Ecosystem Health & Historic Variation; CS-1153 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Eric McDonald; Desert Research Institute – Reno, NV

FY 2000 COMPLETED PROJECT

DESCRIPTION: The primary objective of the proposed project was to determine if key shrub and tree species distributed along first-order channels draining desert piedmonts can provide efficient and reliable signals of environmental change and desert ecosystem health resulting from both natural disturbance and/or military activities. The project focused on the extensive areas of desert piedmont at the U.S. Army Yuma Proving Ground (YPG), Arizona. Three specific objectives were addressed: (1) determine historic range in variation (HRV) of key desert vegetation common to alluvial fan surfaces and first-order rills, including HRV, due to military activities and natural environmental change; (2) evaluate if changes in soil and surface hydrology, due to either military activities and natural environmental variation, can be shown to predominantly account for changes in ecosystem health, especially the historic contraction of vegetation along the margins of alluvial fan surfaces; and (3) provide recommendations that can be used to further develop and test methods or procedures that can be used to monitor ecosystem status and identify impacts related to natural disturbance relative to military activities.

BENEFIT: Results directly advance the knowledge of fundamental soil-hydrology-vegetation processes that are common to desert piedmonts. Evaluation of critical linkages between soils, soil water balance, and desert plant ecology provide information about the impact of climate and military activities on desert shrubs, soils, and archeological sites. Results provide information about how potential changes in the soil and desert pavement surface from military activities may influence other parts of the desert ecosystem.

ACCOMPLISHMENTS: Measurements were made on plants and soils growing at the upper and lower extremes of three independent first order channels on two distinct, different-aged geomorphic surfaces on YPG. Post-spring rainfall measurements of soil moisture (TDR and electromagnetic ground conductivity) and plant response (predawn and mid-day measurements of xylem water potential and photochemical yield) suggest that the assessment of vegetation along first-order drainages provides essential information for detecting change in the status of desert ecosystems. Trends in vegetation health along drainage channels indicate that this part of the ecosystem is sensitive to changes related to either military activities or natural changes in rainfall. Initial results also suggest that a long-term (>50-year) trend in a contraction of vegetation is likely occurring. If true, the source of this contraction is likely due to natural changes in climatic parameters.

The research team monitored and assessed the impact of a large summer storm on soil and vegetation response. The results indicate that infiltration along desert pavements was minimal with most of the rain generating considerable surface runoff, also, suggesting that large, infrequent storms are required to generate sufficient surface runoff and deliver moisture to vegetation along ephemeral channels. Soil moisture and vegetation water potential (midday and predawn) were measured at five intervals following the large storm (between August and November). Comparison of ecophysiological responses following winter rain and response following a large summer storm yield the following preliminary interpretations: (1) Under drought conditions, ironwood and palo verde had high water potentials; shrubs like creosotebush had low water potentials. (2) Soil moisture in upper 1 m cannot account for tree activity. (3) Trees are accessing locally stored soil water, probably 2-5 m deep (vadose zone, NOT groundwater.) (4) All vegetation showed significant response to runoff-generating rainfall. (5) Ironwood and palo verde require adequate transmission loss along channels for survival.

TRANSITION: The results will be used to support immediate land use/management decisions at U.S. Army Yuma Proving Ground (YPG), Arizona. The overall concept and approach has limitless applicability at other arid/semiarid DoD sites as well. Guidelines for applying soil and geomorphic data for predicting impacts of military activities on vegetation along low-order drainages as well as how to monitor for natural change in ecosystem health is required before transitioning to land managers.

PROJECT SUMMARY

PROJECT TITLE & ID: Measures of Ecological Integrity for Salmonid Streams in the Pacific Northwest; CS-1154 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Christopher May; University of Washington, Applied Physics Laboratory – Seattle, WA

FY 2000 COMPLETED PROJECT

DESCRIPTION: Military bases in the Pacific Northwest (PNW) contain valuable aquatic habitat that supports several threatened or endangered species of salmonid. The goal of this project will be to determine a suite of ecological-based indicators for freshwater, aquatic ecosystems to measure environmental change resulting from a shift in natural disturbance regime due primarily to the cumulative effects of watershed development in general, and military operations in particular.

BENEFIT: This projects assists Department of Defense (DoD) installations in the PNW to be proactive in section 7 ESA consultations. This will mean more certainty of uninterrupted military operations and training as well as preserving and enhancing aquatic habitat under DoD stewardship. This research will facilitate DoD installations becoming leaders in managing salmonid populations in watersheds under their jurisdiction and allow base commanders to work seamlessly with state and local jurisdictions on watershed planning and salmon recovery plans.

ACCOMPLISHMENTS: The project investigated a range of physical, chemical, and biological parameters that could be used as tools for assessing changes in natural, aquatic ecosystem structure and function resulting from military activities within the study watersheds. Additionally, the team evaluated existing stream/wetland assessment protocols used in the region for applicability to military installations and their associated natural resources. These will include Federal, state, local, and tribal agencies charged with similar responsibilities. Based on watershed analysis and field surveys, a multi-metric suite of ecological indicators was developed.

The project generated a regional database relating the degree of watershed disturbance and ecological integrity to salmonid utilization, including abundance and species composition, and instream habitat quantity and quality. A management framework was developed for stream ecosystem protection and restoration based on active management for natural ecological integrity. A set of guidelines were established for the various military operations to minimize their impact on aquatic resources. The project established a standard suite of protocols to measure physical (hydrologic, geomorphic, and habitat related), chemical, and biological components of ecological integrity for streams found on military installations in the PNW region. Habitat assessment protocols focused on instream salmonid habitat and riparian/streamside forest habitat.

TRANSITION: The resulting management framework has potential use over a range of environmental conditions found on DoD installations in the PNW. The results of this research have high transition potential with respect to cost-effective application to a wide range of DoD facilities in the PNW and other regions of the country.

PROJECT SUMMARY

PROJECT TITLE & ID: Feasibility Study: Lab-on-a-Chip & In-Situ Bioassay Techniques for Rapid Resolution of Ion Signatures for Disturbances of Bio Significance in Streams; CS-1161 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Arthur Stewart / Mr. John G. Smith; Oak Ridge National Laboratory – Oak Ridge, TN

FY 2000 COMPLETED PROJECT

DESCRIPTION: Soil disturbances are expected to generate characteristic "chemical signatures" in runoff water. Streams in clear-cut watersheds, for example, have very different ion-export patterns, compared to streams in non-disturbed watersheds. The main objectives of this project are to review the prospects and limits to the ideas that (1) "lab-on-a-chip" technology (or in situ measurement of ions and water-quality properties, such as alkalinity, hardness and conductivity) can be used to decipher relationships between physical disturbances on land and ion balance in surface-runoff, receiving-water systems, and (2) in situ bioassays can be used to reveal biological effects of changes in receiving-system ion balance.

The technical approach explored the feasibility of using automated "lab-on-a-chip" methods to acquire time-series data that relate to several conservative and semi-conservative properties of water known to be diagnostic of biological activity and man-related disturbance. A screening survey of several streams on or near the Fort Hood Reservation was conducted based on (1) the availability of calcium-sensitive species of invertebrates that can be used to provide biological responses to calcium-concentration changes in short-term in situ bioassays, and (2) locations that provide a range of disturbance conditions. Additionally, a literature search was conducted on in situ bioassay techniques.

BENEFIT: The expectation is that faster "smart monitoring" techniques that consider chemical and biological variance at shorter-than-conventional time-scales can reduce the monitoring costs and time needed to obtain predictive data, and increase the accuracy of predictions about environmental damage and ecological recovery.

ACCOMPLISHMENTS: The project summarized the feasibility of lab-on-a-chip technology and concluded that chip-based techniques for the colorimetric analysis of alkalinity and hardness are feasible. Signal stability and reproducibility were raised as important considerations to improve pH-measuring capabilities. The prevention of biofouling and clogging of the chip's channel was identified as an engineering challenge only. Screening survey of the chemical, physical, and biological characteristics of seven sites in three streams on Fort Hood were completed. The streams selected represent a continuum along a disturbance gradient. The results provide information needed for formulating a path forward to develop, test, and verify an advanced monitoring technique that combines lab-on-a-chip technology with in situ bioassays. An extensive literature search was conducted on in situ bioassay techniques with three commercially available databases and the North American Benthological Society's database of their published bibliographies on benthic science. The search concluded that a variety of bioassay techniques exist, particularly in situ techniques, that can be used or modified to provide method validation and incorporation into an approach that has predictive capabilities. The project submitted a list of recommended tasks needed to advance the development of the technology.

TRANSITION: This technology will provide access to real-time data that can be used to model calcium speciation, discern inputs from ion-rich terrestrial areas, and predict biological responses. Radiotelemetry of data obtained by lab-on-a-chip analysis techniques is another potential avenue to advance. Remote sensing and reporting methods for environmental media, particularly those that "push the envelop" towards microminiaturization of analytical devices, are useful to DoD and DOE for reasons of environmental security; environmental compliance; environmental clean-up; and better management of DoD lands to minimize onsite environmental damage and offsite migration of pollutants. Such devices would also be of significant interest to National Aeronautics and Space Administration (NASA), Department of the Interior (DOI), the United States Department of Agriculture (USDA) and Environmental Protection Agency (EPA) for related reasons.

PROJECT SUMMARY

PROJECT TITLE & ID: Acoustic Monitoring of Threatened and Endangered Species in Inaccessible Areas; CS-1185

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kurt Fristrup; Cornell University – Ithaca, NY

FY 2001 FUNDS: $255K

DESCRIPTION: Large parcels of known or suspected TES habitat are in areas that are inaccessible to ground personnel because of operational restrictions or unexploded ordnance. Because biologists are unable to use traditional ground-based survey methods in these areas, this project will develop an airborne monitoring system for taking censuses of acoustically active species from the air.

The monitoring system will consist of three components: (1) a microprocessor-controlled digital data recording system that can be deployed either on the ground or on an airborne platform; (2) a helium-filled lift vehicle that can carry the recording system aloft for drifting or tethered deployments; and (3) a software package for automatic extraction, identification, and localization of sounds of interest. All three components represent plausible extensions of technologies that have been successfully implemented by the Cornell Bioacoustics Research Program and its affiliates. The completed system will enable long-term or wide area acoustic monitoring, with fully automatic data reduction. Post-deployment processing will be capable of producing a map of sound source locations and a log of species and time of call for all detections of interest. Summary statistics regarding call density, the estimated density of animals, and measures of the uncertainty of these estimates will be produced. Fully functional systems will be provided to Fort Hood, Texas (the proposed field site) for surveys of golden-cheeked warbler, black-capped vireo, and Bell's vireo. The ability to extend this technology to other bases and species will also be demonstrated.

BENEFIT: This project will result in deployment of a fielded system that will enable natural resource managers at Fort Hood to obtain data on the presence and distribution of the endangered golden-cheeked warbler and black-capped vireo within the 60,000-acre live fire area. Such data have previously been either sparse or non-existent (depending on exact location) because of access restrictions to this area.

In the long term, application of the tools to be developed in this project should reduce the cost and operational impact of conducting biological surveys in areas where such surveys interfere with military operations. The resulting data will support the development and implementation of management plans to protect TES and their habitats while minimizing impacts on the military mission.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: The equipment and methods to be developed in this project will be applicable to monitoring acoustically active TES that occur at other DoD installations, such as the red-cockaded woodpecker (Fort Bragg, Fort Benning, Fort Stewart), Mexican spotted owl (Fort Huachuca), and least Bell's vireo (Camp Pendleton).

PROJECT SUMMARY

PROJECT TITLE & ID: Riparian Ecosystem Management at Military Installations: Determination of Impacts and Restoration and Enhancement Strategies; CS-1186

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Patrick Mulholland; Oak Ridge National Lab, Environmental Sciences Division – Oak Ridge, TN

FY 2001 FUNDS: $391K

DESCRIPTION: Military activities can have negative impacts on riparian ecosystems. DoD recognizes the critical importance of riparian ecosystems as habitat and controls on adjacent aquatic ecosystems. To help DoD better balance land stewardship with its training missions, this project is designed to increase understanding of riparian functions and stresses, and the ecological effects of specific riparian restoration strategies. Two objectives will be addressed: (1) the identification of impacts of upland (erosion) and riparian disturbances (denudation, fire) on riparian functions; and (2) the evaluation of the effects of riparian restoration involving woody debris additions and revegetation to channels. Impacts of current stresses on riparian functions will be based on measurements and comparison of these measurements in catchments at Ft. Benning, GA. Both reference catchments and disturbed catchments that represent a range of disturbed conditions will be monitored and characterized. The degree of disturbance or disturbed condition of a catchment is determined by the percentage of denuded land. Riparian and stream characteristics and processes will be quantified in each catchment. Soil and vegetation measurements will used to define riparian processes. Stream measurements include hydrologic, nutrient and sediment concentrations, metabolic, and periphyton and macroinvertebrate communities. The restoration phase of this project involves woody debris additions in ephemeral channels and 1st/2nd order streams of highly disturbed catchments. Revegetation, using native grasses and woody vegetation, will be conducted in highly disturbed ephemeral channels. The efficacy of the two riparian management restoration strategies (i.e., woody debris additions, and revegetation) to relieve stresses and improve riparian ecosystem functioning will be evaluated.

BENEFIT: The long-term benefit of this project is an increased understanding of riparian ecosystem functions, how military training activities can impact those functions, and how land management activities at military bases can be designed to reduce or eliminate these impacts. The results of this research will provide managers with the information needed to make better land management decisions and more effective restoration plans that can sustain military base ecosystems and the training missions they support.

ACCOMPLISHMENTS: This is an FY 2001 New Start.

TRANSITION: This project will provide prioritized and simplified riparian assessment metrics and protocols which can be used to help facilitate the development of riparian restoration and adaptive management support tools for land managers and military trainers. Additionally, projects findings and data will be immediately useful and integrated into SERDP Ecosystem Management Project (SEMP) which is a long-term monitoring and research initiative at Ft. Benning, GA.

PROJECT SUMMARY

PROJECT TITLE & ID: Acoustic Response and Detection of Marine Mammals Using an Advanced Digital Acoustic Recording Tag; CS-1188

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Peter Tyack; Woods Hole Oceanographic Institute – Woods Hole, MA

FY 2001 FUNDS: $350K

DESCRIPTION: This project will quantify the probability of passive detection of marine mammals in Navy range waters which is currently hindered by an absence of information regarding the vocalization rate, level, and spectral characteristics for many marine mammals found in Navy range waters, especially deep-diving whales. The second objective is to evaluate the short- and long-term impacts of Defense activities on marine mammals. Woods Hole Oceanographic Institution (WHOI) has developed a miniature digital acoustic tag, the DTAG, that provides high fidelity, on-animal recordings of vocalizations and ambient sound. The tag also includes orientation and dive sensors, and provides a uniquely direct means for establishing the behavioral response of a whale to an impinging sound. This project will perform a series of field experiments combining surface observations with on-whale recordings using the DTAG.

Three types of experiments will be completed. Focal follows of tagged animals will produce a database of vocalizations from whales with identified species and behavior. These data will be used to estimate vocalization rates. The second experiment involves simultaneous recordings of vocalizations at a tagged animal and at range hydrophones. The result will be a set of reference recordings from animals of known position and species, which can be used to evaluate, and enhance, passive detection, localization, and classification algorithms. Finally, controlled exposures of Navy-related sounds will be made to tagged animals to determine if, and under what conditions, deep-diving whales react to man-made sounds. The results will be used to help quantify safe exposure levels for the test sounds and to establish a paradigm for testing other sound sources.

BENEFIT: The project research on short-term impacts of naval sound sources will provide critical data for developing protocols for operating these sources in ways that comply with federal environmental laws. Without this information, there is a risk either that these sounds may adversely impact protected populations or that protective measures taken as a precautionary measure because of ignorance may impact naval operations. Passive acoustic monitoring is one of very few methods suited to evaluating the long-term impact of naval operations. Once this technique has been tested and validated, it offers a non-invasive, cost-effective method to monitor vocal behavior and distribution of vocalizing animals for months before an operation, during the operation, and for months after the operation. This capability will be of growing importance, once short-term impacts have been elucidated.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: The results of this project will be transitioned into the Navy's marine mammal protection program. The data will provide vocalization databases required to assess the probability of detecting animals on Navy ranges. In addition, the team will work with range acousticians and signal processors to provide a biological perspective.

PROJECT SUMMARY

PROJECT TITLE & ID: Acoustic and Visual Monitoring for Marine Mammals at the Navy's Southern California Off-Shore Range; CS-1189

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Hildebrand; University of California, San Diego – La Jolla, CA

FY 2001 FUNDS: $290K

DESCRIPTION: The Southern California Off-Shore Range (SCORE) is a region where naval operations are frequently conducted and where marine mammals are known to be abundant. The technical objective of this project is to compare methods for actively monitoring marine mammals within the SCORE region using the following four techniques: (a) aerial surveys (visual), (b) ship-based transect surveys (visual), (c) sonobuoy-based mobile acoustic surveys, and (d) continuous fixed-site acoustic surveys.

Simultaneous application of these techniques will allow their comparison to determine the combination of methods most suitable for long term monitoring of the SCORE range. In addition, this project will investigate the contribution of environmental factors, such as sea surface temperature, to make an environmentally based model for marine mammal presence. This research will allow for better understanding of marine mammal presence within SCORE and improve techniques for studying marine mammal presence at other sites of naval interest.

BENEFIT: There is a high priority Navy requirement for data on marine mammal locations and seasonal densities within areas of frequent naval operations. The acoustic population estimation techniques developed by this project offer the potential for efficient and economical monitoring of marine mammals. These techniques are a first step in understanding the impact of sound on marine mammal behavior. This is an area of intense research by the Office of Naval Research and the Chief of Naval Operations (N45) with respect to environmental compliance issues.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: Research findings will transition for use by SCORE personnel as a real time system for marine mammal detection and classification, as a database of seasonal marine mammal presence within SCORE, and as a predictive model for marine mammal association with environmental conditions. Marine mammal density estimates, as a function of both time and location as produced by this project will be integrated into a planning tool for use by the Navy. Development of acoustic techniques for marine mammal population assessment will also transition into the larger marine mammal science community. Passive acoustic monitoring can be applied as a complimentary technique to traditional visual survey such as those conducted by the National Marine Fisheries Service (NOAA).

APPENDIX D

Pollution Prevention Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: Trapped Vortex Combustor for Gas Turbine Engines; PP-1042

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. W. M. Roquemore; U.S. Air Force Research Laboratory – Wright-Patterson Air Force Base, OH

FY 2000 COMPLETED PROJECT

DESCRIPTION: The purpose of this project was to provide the design basis to demonstrate the capability of a trapped vortex combustor (TVC) to reduce pollutant emissions. The TVC technology is proposed for use in aircraft and in stationary gas turbine engines used on naval vessels. The goals of this project were to demonstrate the feasibility of developing a TVC that will: (1) reduce aircraft pollutant emissions [nitrogen oxides (NOx), volatile organic compounds (VOC), carbon monoxide (CO), and particulate matter (PM)10] by 60 percent, bringing them significantly below the proposed 1996 Environmental Protection Agency (EPA) regulations; and (2) reduce NOx emissions from a stationary gas turbine by 60 percent, bringing these NOx emissions below the California Resource Board recommendation of 42 ppm and the 1995 EPA regulation for land and marine based gas turbine engines burning distillate fuels.

The project successfully demonstrated feasibility of the TVC concept at operating conditions consistent with those of military gas turbine engines used in aircraft and for power stationary generation. The TVC departs from the traditional swirl stabilized designs used in gas turbine engines for the past 40 years. It has two parts, a pilot combustor for stability and a main combustor for power. The pilot utilizes cavities to establish the recirculation zones needed for stable combustion. Each cavity is sized to provide a stable recirculation zone that is referred to as a "trapped vortex". Fuel and air are injected into the cavities in a way that reinforces the vortex that is naturally formed in the cavities. General Electric (GE) and the Air Force Research Laboratory (AFRL) worked together to design and evaluate the TVC concept. The technical approach combined a Computational Fluid Dynamics (CFD) design study with an experimental sector rig study to investigate different TVC configurations at realistic conditions and with realistic size combustors. Three different missions for a TVC are being considered. The first mission corresponds to a future high performance aircraft. The second mission corresponds to low emissions high performance engine upgrades for conventional aircraft. The third mission corresponded to possible future forward-fit for new purchases of Land/Marine (LM) 2500 engines used aboard Naval vessels.

BENEFIT: If all existing military aircraft had a TVC, the VOCs for the Air Force and Naval bases could drop by as much as a factor of 10. Depending on the aircraft type on the base, the NOx emissions could be reduced by 20 to 40 percent. This NOx reduction would permit flight operations and training to continue with reduced or no fines. If commercial aircraft also had TVCs, then the environmental and cost impact could improve by a factor of 8. Once implemented, the TVC technology would also consume less fuel, further reducing emissions.

ACCOMPLISHMENTS: The Air Force and GE jointly developed a novel combustor technology concept for potential applications in gas turbine engines. The prototype TVC test rig exceeded all initial expectations. Major performance highlights are:

- 40 to 60 % NOx emissions reductions compared to 1996 International Civil Aviation Organization (ICAO) standards
- 55% estimated reduction in yearly NOx emissions from Navy ships currently operating with an LM2500 engine

- 50% improved ground ignition, altitude re-light, and lean blow out margins compared to conventional combustors

- Above 99% combustor efficiency maintained over 40% wider range than conventional combustors.

As seen below, TVC achieves approximately 60% reduction in NOx emissions relative to current production engine combustors and performs very favorably compared to the advanced "Dry Low Emissions" combustors.

Relative Emission Rates in Total Pounds per Year			
Technology	**CO**	**HC**	**NOx**
Current (dry)	1.0	1.0	1.0
Current (wet)	1.16	1.11	.63
Adv Dry Low Emissions	.61	1.32	.65
TVC	.95	.60	.41

TRANSITION: Full-scale demonstration/validation is expected in FY05 under the ESTCP. The TVC is targeted for the following products: (1) a new high performance aircraft engine; (2) retrofit for upgrading existing engines; and (3) forward fit of new LM2500 engines for Naval vessels.

PROJECT SUMMARY

PROJECT TITLE & ID: Eliminate Toxic and VOC Constituents from Small Caliber Ammunition; PP-1057

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. John Middleton; U.S. Army Armament Research, Development, and Engineering Center – Picatinny Arsenal, NJ

FY 2000 COMPLETED PROJECT

DESCRIPTION: The goal of this project was to develop non-toxic small caliber ammunition which will meet U.S. North Atlantic Treaty Organization (NATO) performance standards for 5.56 mm, 7.62 mm, 9 mm, and 50 caliber. The research focused on eliminating toxic components in the materials and manufacturing processes for the small caliber projectile core and primer. The solutions need to be economical and feasible, while meeting environmental regulatory guidelines and standards over the life cycle of the cartridge.

For the projectile core, environmental studies of candidate projectile core materials were conducted to determine their viability in a non-toxic projectile and optimize methods for recovery and minimum release to the environment. The battery of environmental tests included leaching, corrosion, and biological uptake. These tests provided guidance for optimizing the environmental stability, recovery, and recyclability of the next generation projectile materials. The biggest concerns were the terminal ballistic performance and mobility/toxicity of materials.

For the cartridge primer, a new class of non-toxic energetic materials called metastable interstitial composites (MIC) were evaluated as a replacement for current primer materials which included lead styphnate, barium nitrate, and antimony sulfide. A MIC material is an engineered energetic consisting of two or more chemical species that are exothermically reactive with each other. Major concerns were: (1) MIC compounds had never been used before in small arms percussion primers; (2) Verification of the temperature output from the MIC composition upon ignition; (3) Performance of these materials when subjected to high rates of fire such as in a minigun. Long-term storage tests of the final design would also be required.

BENEFIT: The elimination of waste removal at outdoor firing ranges will save $2.5 million and the elimination of lead monitoring will save $100,000 annually. There are 601 currently closed National Guard indoor small arm ranges that will no longer require $150,000 to remain open for a total savings of $90 million. The elimination of lead sludge treatment at Lake City Army Ammunition Plant will reduce costs by $100,000 annually. Finally, when the automated MIC process is implemented, manpower reductions will save $750,000 annually.

ACCOMPLISHMENTS: The successful development of environmentally friendly tungsten-based projectile core materials will replace lead-antimony projectile core materials for the 5.56 mm, M855 ammunition. Additionally, this success has resulted in plans to expand technology to other small calibers such as 7.62 mm and 9 mm. The tungsten toxicology and chemical stability/leaching studies were completed for use as an essential information resource to eliminate heavy metals from other ammunition items.

To replace lead styphnate based primers, which contain barium and antimony, the investigation of MIC energetics has resulted in successful demonstration of an equal-to-baseline-velocity MIC material that meets operational extreme cold temperature (-65 degrees F) requirements, a key parameter that has eluded non-toxic primer research throughout the 1990s. Since MIC is a heat generator only, propellant ignition performance reliability has been reduced, so hybridization of the MIC material with gas and spark generating compositions was explored to optimize chemistry. The fabrication of MIC constituents has been quantified and successfully demonstrated through the development of characterization methods. It is hoped as the MIC process is scaled up, manufacturing and yield will improve.

TRANSITION: ARDEC, the lead laboratory for the ammunition Single Manager, will work with industry and the Lake City Army Ammunition Plant (LCAAP) to facilitate transition of results into products ready for use in the field. Production of 5.56 mm, M855 lead-free ammunition begins in FY01 and the Army goal is to fully transition by FY05. A MIC full-scale demonstration/validation is proposed through ESTCP in FY 2001.

PROJECT SUMMARY

PROJECT TITLE & ID: Elimination of Toxic Materials and Solvents from Solid Propellant Components; PP-1058

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Stanley; U.S. Army Aviation and Missile Command – Huntsville, AL

FY 2000 COMPLETED PROJECT

DESCRIPTION: The overall goal of the "Green Missile" program was to eliminate major sources of toxic/hazardous materials used in solid rocket propulsion systems. The objectives were to: (1) develop lead-free extrudable and castable propellant for minimum smoke systems; (2) develop complete and clean, HCl-free, combustion of propellant; (3) develop solvent-less methods for processing energetic oxidizers; and (4) develop thermoplastic elastomer based inhibitors. The technical risk of this research was that the materials developed may not have the necessary propulsion characteristics.

Lead Elimination: Propellants containing ammonium nitrate (AN) with CL-20 or AN with RDX were developed further to optimize combustion properties. Combinations of CL-20 and ammonium dinitramide (ADN) developed, the chemical and physical properties of their different material forms were characterized, and their formulation and processing were evaluated. Formulations containing alternative materials such as bismuth salicylate or bismuth citrate were evaluated. For extrudable propellants, the filled double base and the extruded composite lead-free alternatives were scaled-up to larger pilot plant mixers to more fully characterize physical and ballistic properties. Runs of thermoplastic elastomer (TPE) propellant formulations were transitioned from torque rheometer and small-scale horizontal mixer to the pilot plant twin screw extruder.

HCl Elimination: Research continued to evaluate ultrafine aluminum (UFAL) and/or ADN propellant compositions using low-solid content and energetic plasticizers to give highly efficient and clean burning propellants while meeting performance requirements. In collaboration with the Air Force Research Lab at Edwards AFB, UFAL were characterized to determine particle size distribution, particle shape, and surface area. Propellant compositions were optimized and evaluated.

Clean Oxidizer Processing: The solventless process set up for preparation of molding powders on the 100 gm scale by coating RDX with dioctyl maleate (DOM) using supercritical carbon dioxide was modified in order to utilize supercritical propane to coat RDX with polyethylene. Solventless production of polyethylene-RDX molding powders were demonstrated, process conditions were optimized, and the molding powder was characterized. The pressed explosive properties of the molding powder was evaluated. A cost/benefit analysis comparing this process with a solvent-based process and a solvent/liquefied gas non-solvent-based process was performed. The existing technology base of the antisolvent comminution process for high energy oxidizers was further developed and enhanced.

TPE Development for Solid Rocket Motor Propellant: Three different polymeric inhibitor systems were evaluated as potential replacements for the baseline cellulosic inhibitor. Research and development tasks included production of the polymeric candidates, characterization of the physical properties of the polymers, performance of adhesion tests of the candidate polymers with motor propellant candidates, and scale-up synthesis for evaluation.

BENEFIT: Immediate benefits from the research are: (1) a lead-free formulation for HELLFIRE and the Tri-Service 2.75 inch rocket, solving 95% of the current lead emission problems; (2) an HCl-free formulation for MLRS, eliminating HCl emissions that can endanger ground forces and damage ground equipment; (3) a solventless energetic oxidizer process for HELLFIRE, a solution for 60% of the AND/CL-20 systems and a new process for the manufacture of polyethylene/RDX molding powders and (4) a solventless method for application of inhibitor. With technology transfer to similar systems, the potential overall cost savings from the research are $1.5M from lead elimination and $3M with solvent elimination/minimization.

ACCOMPLISHMENTS: Activities on this program are nearing end with projected completion of the project slated for the end of the calendar year. Development of the final report has commenced. Specific accomplishments are as follows:

Lead Elimination: AMCOM continues preparation for test firing of rocket motors cast with newly formulated lead-free (bismuth ballistic modifiers, bismuth citrate, bismuth salicylate) propellant. The 2.75 Rocket motors were test fired at different temperature extremes. Two bismuth compounds were incorporated into high performance propellant formulations and evaluated for processing, ballistic, mechanical, signature, and aging properties. Acceptable test results were achieved in all evaluations. Propellant performance properties were at least equal to current formulations containing lead and superior in other important properties. Two lead-free propellants were successfully tested in TOW missile and 2.75 Rocket configurations.

HCl Elimination: The UFAL-AND formulation has been produced on a pint scale and cast into six 140-gm motors for testing. Formulations using bis-(aminotetrazolyl) tetrazine (BTATZ) as a burn rate modifier have allowed a marked decrease in the slope. An alternate cure system for azides and UFAL is being investigated and mechanical property optimization is continuing.

Clean Oxidizer Processing: An increased process efficiency to greater than 99% oxidizer recovery was achieved and recycling of processing solvent has been demonstrated. Multimodal comminuted particles were generated and comminuted RDX oxidizer materials were available for independent evaluation in Navy missile formulations. Performance of reclaimed comminuted RDX was compatible with virgin RDX in a propellant formulation.

TPE Development: The program for the development of the POSS-Polynorbornene polymer as an inhibitor has been completed. The polymer was successfully scaled up to 100g batches with a 66% reduction in the amount of solvent used. The material was then extruded and pressed into a 2 mm thick sheet. Minimal heating of the sheet (<80 °C) allowed for enough flexibility to easily wrap around the inert propellant while also resulting in a strong adhesion to the propellant. Another sheet was made and sent to Indian Head for live propellant firing. AFRL has also decided to test the material as a thermoplastic Solid Rocket Motor insulation.

TRANSITION: Program Managers/Program Executive Officers for HELLFIRE, Tri-Service 2.25 inch rocket, and TITAN are prepared to endorse this technology when successfully demonstrated.

PROJECT SUMMARY

PROJECT TITLE & ID: Next Generation Fire Suppression Technology Program; PP-1059

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Richard Gann; National Institute of Standards and Technology, Building and Fire Research Laboratory – Gaithersburg, MD

FY 2001 FUNDS: $2600K

DESCRIPTION: Halon 1301, the predominant and critical total flooding fire suppressant installed in weapons systems, is no longer in production due to its deleterious effect on stratospheric ozone. The objective of this program is to develop and demonstrate, by 2005, environmentally acceptable and user-safe processes, techniques and fluids that meet the operational requirements currently satisfied by Halon 1301 systems in aircraft, ships, land combat vehicles, and critical mission support facilities. The results will be specifically applicable to fielded weapons systems and will provide dual use fire suppression technologies for preserving both life and operational assets. This effort leverages prior SERDP-funded research and the Research Development, Test, and Evaluation (RDT&E) infrastructure created under the ongoing Department of Defense's (DoD's) near-term research program.

The research approach consists of six parallel Technical Thrusts, closely integrated to achieve specific milestones within an 8-year time frame. This approach was developed collaboratively by government, industry, and academic experts in fire science, the contributing technical disciplines, instrumentation, testing, and Halon 1301-protected weapon systems. Following are the six Technical Thrusts, which embody 24 separate research elements.

1. Risk Assessment and Selection Methodology develops a process for choosing among alternative technologies by applying modern decision-making concepts.

2. Fire Suppression Principles establish the mechanisms of flame extinguishment using detailed experimental studies and computational models leading to new approaches for fire control.

3. Technology Testing Methodologies select, adapt, and develop test methods and instrumentation to obtain data on the effectiveness and properties of new suppression approaches.

4. New Suppression Concepts define new ideas for fire suppression based on chemical and physical principles.

5. Emerging Technology Advancement accelerates a variety of processes, techniques, and fluids that are currently under development.

6. Suppression Optimization develops the knowledge to obtain the highest efficiency of each candidate technology.

This is a "living" program, representing the best current thinking for achievement of the objective, yet adaptable as the knowledge base grows. There are always risks in such an undertaking. For instance, there might be no chemicals that perform well for all the desired properties; no new fire suppression technologies might emerge; optimization principles might not improve mediocre approaches sufficiently; and lab-scale measures might not adequately predict real-scale performance. This research is designed to provide the scientific understanding to maximize the likelihood of overcoming risk factors.

BENEFIT: The outcome of this program will be demonstrated alternatives to Halon 1301. This will enable DoD weapon system managers to remove their dependence on a key ozone-depleting substance while minimizing fiscal and operation barriers to implementation.

ACCOMPLISHMENTS: The NGP is developing both improved understanding to guide the search as well as identifying candidates worthy of further consideration. The following is a list of highlights achieved in FY00:

- Identified candidates worthy of further consideration for economical ways to effect retrofit of a fire suppression system.
- Developed a model for how fire suppressant additives quench flames.
- Examined over 1500 thermal agents identified about 25 compounds which might be suitable fire fighting agents, some of which are already in use.
- Developed the first bench-scale suppression screen for comparing the flame extinction performance of both gases and liquids that can also be adapted for powders. The Dispersed Liquid Agent Screen (DLAS) is now in steady use both to obtain suppression efficiency data on candidate suppressant fluids and as a research tool. A second NGP apparatus can screen the effectiveness of a short burst of suppressant, such as would emerge from a solid propellant gas generator (SPGG).
- Sponsored completion of a physiologically based pharmacokinetic (PBPK) model of a human system that incorporates a breath-by-breath description of respiration and follows the inhaled suppressant to the bloodstream.
- Continued research directed at finding new approaches to condensed phase candidates and ways to improve the use of current suppressants. Fine water mist and efficient powders have been the subjects of real-scale testing.
- A unique set of computer programs for estimating the thermophysical property data for fluids is now operational. As the NGP examines new fluids, some not commercially available, and as solutions emerge as serious candidates (e.g., aqueous sodium lactate), these estimates will become pivotal.
- Completed and validated a new computer code for the prediction of transient, two-phase fire suppressant flows through a complex pipe run, enabling determination of the change in discharge rate when substituting a new suppressant into the current piping.
- Developed and validated a model to describe the rate of agent entrainment into flames behind different shapes of obstructions. The model develops design criteria for the free stream agent concentration and injection period needed for extinguishment.
- Developed a measurement of the distribution of the suppressant approaches based on two distinct principles: laser-induced breakdown spectroscopy and infrared absorption.
- Developed a time-resolved (10 ms), multi-point, fieldable, near-infrared tunable diode laser-based sensor for measurement and detection of combustible mixtures of oxygen and hydrocarbon fuels during fire suppression.
- Designed a fiber optic probe for use at temperatures up to 1200 K in the presence of powder, smoke, and fine water mist.
- Developed a methodology to quantify a fire suppression technology by its life cycle cost and to enable superimposing on this a subjective value system. The data gathering for and formation of the baseline (halon 1301) case has been completed, as has the structuring of the cost benefit analysis process. This provides a framework for evaluating a range of weapons systems, considering both financial and technical variables.

TRANSITION: This is an eight-year, comprehensive research and development (science and technology) effort with leveraged funding from all DoD Services, industry, and academia. Successful sub-projects will be further developed within this program. "Spin offs" to various weapons systems development programs are anticipated.

PROJECT SUMMARY

PROJECT TITLE & ID: Tri-Service "Green" Gun Barrel – A Physical Vapor Deposition for the Application of Environmentally Safe Coatings for Gun Barrel Bore Protection; PP-1074

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Vasilakis; U.S. Army, Benet Laboratories – Watervliet Arsenal, NY

FY 2001 FUNDS: $550K

DESCRIPTION: This project will develop an innovative dry (non-aqueous) process for the deposition of chromium or other materials equally suited to the bore protection of a gun barrel to replace the aqueous electrodeposition process. This novel process is called the Cylindrical Magnetron Sputtering (CMS) process. The project will result in an advanced technology demonstration addressing specific Army, Navy, and Air Force requirements in the plating of the Medium Caliber Barrels. Moreover, it will show that the work can be spun off to Large Caliber Gun Barrels and other applications including cylinders for recoiling mechanisms, aircraft landing gear, the oil processing industry, the power generation industry, and the mining and exploration industry.

CMS is a dry, environmentally clean technology capable of depositing chromium on gun tubes. It also has the flexibility to deposit other refractory metals and their alloys as well as being able to tailor the coating properties through the deposition thickness. Although the focus is on chromium, the deposition of alternate materials, such as tantalum, will eliminate environmental problems as well as provide improved bore protection, will be evaluated. If chromium were deposited, environmental problems can still exist because a "consumable" chromium target would have to be made, most likely, by the same electrodeposition process that this project seeks to eliminate. Initial efforts will focus on developing the facility for investigating a single medium caliber size and the parameters required for depositing a well-adhered, uniformly-coated tubular section. Once established, the facility will be sized to accept the different caliber gun tubes provided by the Tri-Service partners. These will be returned to the partners for firing tests. Leveraged support is through universities, other government agencies, and industries. Some of this support is through additional funds while other support is through exchange of services. Where necessary, Cooperative Research and Development Agreements (CRADAs) will be developed if non-existent.

BENEFIT: Current weapon systems and those currently being developed or planned will have gun tubes with chromium deposited on their interior/bore surface to protect the bore surface from the hot propellant gases and the mechanical effects of the projectile. Current technology relies on an wet process known as aqueous electrodeposition. The chromic acid used in the deposition process contains hexavalent chrome, a known carcinogen that is extremely expensive to manage and dispose. For example, in FY95 for large caliber barrels, the cost of wastewater treatment and sludge removal was $2.3M. This program will develop a dry, environmentally clean replacement process for aqueous electrodeposition chromium plating facilities.

ACCOMPLISHMENTS: The 6" laboratory demonstrator has been extensively used to continue the investigation of sputtering parameters and to explore new areas for improving morphology and texture, as well as new approaches for geometric changes and system design and efficiency. The demonstrator uses a 6-inch long 25 mm diameter specimen. Results from planar magnetron studies have given us guidance on the sputter pressures required to develop a uniformly distributed alpha-Tantalum phase on the substrate. Improved results with increased substrate temperatures have been achieved. A laboratory demonstrator was also used to begin considering the effect of plating on rifling. The M242 Bushmaster and GAU-12 are both rifled. The result was successful as the coating was uniform over the lands and grooves within a small percentage and there was no buildup on the edge or nodules.

The tower/demonstrator for plating a full length Bushmaster was completed. A cut-off (55-inch long) Bushmaster section was installed. Successful vacuum pump down and plasma development in the gun were achieved. As it was difficult to get a uniform plasma on the small 25-mm diameter gun tube, current efforts are focused on redesign of the center conductor.

TRANSITION: There is Tri-Service support for the program and typical medium caliber barrels from each of the Services will be coated with the new process and test fired at each of their respective facilities. The program is also heavily leveraged with others from not only the environmental area, but also from gun barrel wear and erosion areas. Industry has provided information to the program regarding environmental costs and has indicated interest in applying the technology after development.

PROJECT SUMMARY

PROJECT TITLE & ID: Replacement of Non-Toxic Sealants for Standard Chromated Sealants; PP-1075

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Alan J. Fletcher; U.S. Air Force Research Laboratory – Wright Patterson Air Force Base, OH

FY 2001 FUNDS: $290K

DESCRIPTION: The objective of this work is to formulate and test candidate non-chromated sealants that will provide equivalent or improved properties as compared to the existing chromated sealants while meeting the requirements of MIL-S-81733C. An additional goal is to reduce the volatile organic compound (VOC) content of the materials by 65 percent.

Sealants are required in aircraft systems and on weapons to provide protection against corrosion, prevent moisture entry, provide a fuel barrier, and provide electrical insulation. Traditionally, sealants use chromium as the primary corrosion inhibiting substance. Chromium has been designated as hazardous and is targeted for elimination in order to comply with either current or pending Occupational Safety and Health Administration (OSHA) requirements. Most sealants also contain VOCs such as methyl ethyl ketone (MEK) and toluene. Under this project team's guidance, a chromate-free corrosion inhibiting sealant has been developed, tested and transitioned to the field. A new polymer has been developed that is characterized by properties beneficial to corrosion-inhibiting sealants: rapid cure times without a reduction in work life; a pleasant odor; excellent rheological properties; excellent cure at low temperatures; and high solvent resistance. The proposed work is directed towards use of this new polymer to formulate corrosion inhibiting sealants for all the types and classes of MIL-S-81733.

The approach encompasses the following tasks:

Polymer Selection and Optimization: This task will select, develop and optimize the base polymer system to be used for formulation development. The end result of the task will be a base polymer system that can be used to formulate non-chromated corrosion inhibiting sealants.

Selection of Curing Agents: This task will research, develop and formulate curing agents for the base polymers systems selected. A contract will be awarded to the sealant manufacture from Task 1 to research and develop curing agents for the base polymers systems selected. These curing agents will be non-chrome and minimum VOC compounds that provide the best curing mechanism.

Selection of Corrosion Inhibitor: This task will research, develop, test and optimize non-chromated corrosion inhibitors. A contract will be awarded to sealant manufacturers that have successfully completed Task 2 to research, develop and optimize corrosion inhibitors for their sealant system.

Selection of Sealant Systems: The requirement for each type and class of product will be reviewed by the team and the selection of one sealant system will be made for formulation into a sealant material that will meet the requirements for the intended use of each type and class of material.

Formulation of Sealant Compounds: This task will formulate sealant compounds needed to replace two of the types and classes found in MIL-S-81733.

Formulation Testing: Laboratory or pilot plant batches of each formulation will be tested for the critical requirements of type and class or sealant. Material samples will be provided by the sealant manufacturers to the Air Force Research Laboratory, the Naval Air Warfare Center, and the Army Research Laboratory. These laboratories will test the formulations to the critical requirements of each service.

Candidate Optimization: This task will optimize the promising formulations and will include optimization for ease of application, pilot plant manufacturing and testing, and scaled-up to production batches.

QPL Testing: This task will perform qualification testing on new formulations. Once a formulation has been finalized, qualification testing will be conducted on production batches of the material. MIL-S-81733 and AMS 3265 will be used for qualification test procedures.

BENEFIT: They include: (1) reduced use of hexavalent chromium and VOCs; (2) development of longer shelf-life sealant formulations; (3) development of primerless sealant formulations; and (4) expansion of technology enabling the replacement of other chromated sealants.

ACCOMPLISHMENTS: The development of a prototype base polymer was completed. Also, the development of three corrosion inhibitor/accelerator formulations was completed. Two different methods, electrochemical impedance spectroscopy (EIS) and galvanic current measurements, were used to determine the effectiveness of the candidate corrosion inhibitor packages on both 2024 and 7075 aluminum alloys. Based on this data and the previously observed effects of the various inhibitors on the physical properties of the sealants, non-chromate corrosion inhibitor packages were chosen. These results will guide the development and optimization of the final sealant formulations in subsequent tasks.

TRANSITION: MIL-S-81733 will be revised and implemented throughout DoD to incorporate the new non-chromated sealant compound while meeting all the other specification requirements.

PROJECT SUMMARY

PROJECT TITLE & ID: Non-Polluting Composites for Remanufacturing and Repair for Military Applications; PP-1109

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. James Sands; U.S. Army Research Laboratory – Aberdeen Proving Ground, MD

FY 2001 FUNDS: $800K

DESCRIPTION: The technical objective is to research, develop, and demonstrate a unique, affordable, environmentally friendly family of polymer-matrix composite (PMC) manufacturing and repair technologies for stand-alone repair of current, soon-to-be-fielded, and future DoD structures. Repair concepts and technologies will be demonstrated on DoD-specific problems, including the design and implementation of a non-autoclave repair procedure for the Army's complex integrated polymer composite lightweight armor designs used on the Composite Armored Vehicle (CAV) and the Crusader Self-Propelled Howitzer (SPH); the development, demonstration, and documentation of a repair-friendly processing method for the remanufacture of the Navy's FY02+ fielding of the Advanced Enclosure Mast Sensor System (AEMSS) including multifunctional material development; and the development of several advanced concepts for non-autoclave manufacture and repair of thin composite skins for aircraft and Army rotorcraft.

This Project investigates a variety of novel composite processing and cure methods, including vacuum-assisted resin transfer molding (VARTM), the multi-resin co-injection process, electromagnetic PMC curing techniques, and novel portable radiation (ultraviolet and electron beam) cure techniques to solve pollution problems in composites re-manufacturing and repair for military applications. A key to success is tight control over temperature during processing, reducing residual stresses and providing a consistent glass transition temperature (Tg) and consistent mechanical properties using recently invented composite manufacturing techniques and optimizing them for repair of complex DoD PMC structures.

BENEFIT: Technologies will enable out-of-autoclave processing as well as reduction of emissions from adhesive bonding operations. Used in tandem, these techniques can substantially reduce pollutants and waste in composite repair and remanufacturing. There will be no need for recycling scrap and waste materials by enabling efficient material use and reducing the number of processing steps required for the manufacture of multi-functional PMC components (e.g., Crusader, CAV, and AEMSS) by up to 80 percent. In AEMSS alone, cost savings in excess of $10M over the next 6-7 years are anticipated. The electron beam cured materials are a significant improvement to autoclave cured composites because it affords localized curing in a damaged structure, which eliminates the need for high-VOC and NOx emitting autoclaves.

ACCOMPLISHMENTS: Several electron beam and induction cured materials have been formulated, tested, and evaluated. The best materials have been modified using traditional filler packages to improve handling and performance when possible. Some of the raw materials have been submitted to a major resin supplier to incorporate into potential new marketable resin and adhesive systems that can be processed by electron beam irradiation. Additionally, partners in the SERDP program (Northrop Grumman) have successfully developed and tested high strength adhesive film materials that cure by E-beam irradiation. These film materials have a potentially infinite shelf-life if kept from UV radiation. Further developments and testing are being finalized in this area.

The induction cure processing models for control of heat generation in carbon fiber laminates have been completed. The preparation of induction heated thermoplastic laminates has been demonstrated on a laboratory scale. This technology model will become the foundation for high-throughput laminators for munitions applications in the coming program year. In addition, thermoset adhesive bonding using induction heating has been demonstrated as a strong candidate for field repair of composite structures.

TRANSITION: Systems of interest for the application of these novel manufacturing/repair methods and for specific demonstration of the technologies during this program include Army helicopter blade repair with the new Aviation and Missile Command and Corpus Christi Army Depot (CCAD); the Navy's mast enclosure redesign, remanufacture, and repair procedure development with the Naval Surface Warfare Center; and Navy/Air Force aircraft skin non-autoclave manufacture and repair through Northrop Grumman and Science Research Lab.

PROJECT SUMMARY

PROJECT TITLE & ID: Genetic Enhancement of an Anti-Freeze Protein for Use as a Substitute for Ethylene Glycol for Aircraft Deicing; PP-1110

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Henry; Aspen Systems, Inc. – Marlborough, MA

FY 2001 FUNDS: $237K

DESCRIPTION: Traditional anti-icing/deicing agents are either propylene or ethylene glycol. These agents result in excessive biological oxygen demand (BOD) loading and are toxic to humans, mammals and aquatic species. The clean-up of sites contaminated with these deicers is expensive. For example, at Griffith AFB, NY, the use of glycols as a deicing fluid for aircraft has resulted in ground-water cleanup programs costing over $8.2M. An Air Force policy has been issued banning future purchase of ethylene glycol. The Environmental Protection Agency (EPA) has recently passed regulations that require the construction of on-site collection and treatment facilities for spent deicing chemicals. Under these regulations, waste deicing fluid runoff will be classified as a non-storm water discharge which must have a low BOD and an individual permit if the BOD cannot be eliminated. A successful program will push development of antifreeze proteins as anti-icing agents to enable their application, replacing propylene glycol and urea as anti-icing fluids and solids.

This project goals to develop deicing/anti-icing agents from antifreeze proteins characterized by a BOD substantially lower than the current agents. Initial research has indicated that an arctic beetle, *Dendriodes canadensis*, produces a natural biodegradable protein that can depress a freezing point at 300 to 500 times the predicted value based on its molal concentration due to non-colligative properties. This project seeks to genetically alter the *Dendriodes canadensis* antifreeze protein (*D. can.* AFP) gene in order to enhance its freezing point depression capabilities and increase its ability to function as a deicing/anti-icing agent.

Aspen Systems, Marlboro, MA, is producing a second generation of antifreeze proteins, which have the amino acid sequence of *D. can.* AFP altered within the ice-binding domains. These changes enhance the protein's antifreeze capabilities by increasing the binding affinity and altering its binding specificity for ice crystals.

BENEFIT: Development and use of a deicing/anti-icing agent that is non-toxic and characterized by a low BOD should reduce the costs of the management of deicing/anti-icing operations and minimize the potential environmental impacts from discharge of untreated deicing/anti-icing wastewater to aquatic systems.

ACCOMPLISHMENTS: Mutated *D. canadensis* antifreeze proteins were purified and the capabilities of the protein were analyzed for acute and chronic environmental toxicity using fresh water species, *Ceriodaphnia dubia* and *Pinephales promelas*.

TRANSITION: All Services and the commercial airline industry will be apprized of initial results. Successful candidates may be further tested by Service programs. Validation testing of anti-icing fluids will be done with partners at the Air Force, the Army, and commercial airlines.

PROJECT SUMMARY

PROJECT TITLE & ID: Environmentally Advantaged Substitutes for Ethylene Glycol for Aircraft Ice Control; PP-1111

PRINCIPAL INVESTIGATOR & ORGANIZATION: Ms. Carolyn Westmark; Foster-Miller, Inc. – Waltham, MA

FY 2001 FUNDS: $248K

DESCRIPTION: The technical objective of this program is to develop a high performance, environmentally benign aircraft anti-icing fluid which can be safely released to the environment without capture, control, and post-treatment of the runoff. Specific objectives are to: (1) develop a molecular modeling approach which allows for prediction of non-Newtonian viscosity behavior of materials based on their chemical structure; (2) develop a non-toxic, non-Newtonian thickening agent with enhanced performance capabilities for anti-icing fluids, particularly extended holdover times; (3) select low environmental impact additives for performance enhancement; (4) demonstrate that the anti-icer formulations are compatible with military aircraft materials and weapons systems; (5) demonstrate the ability of the anti-icing formulations to prevent ice formation for extended periods of time in simulated adverse weather environments; (6) predict the water quality impact of new anti-icer formulations at actual airfield sites using computer modeling and laboratory analysis of key environmental parameters; (7) determine any potential health/safety risks of anti-icing formulations; and (8) develop cost-effective anti-icing formulations by screening out excessively costly materials throughout the testing program. The most promising freezing point depressants from an earlier Air Force funded Small Business Innovation Research (SBIR) Phase I program will be used as a basis for anti-icer formulations.

The Foster-Miller strategy to develop environmentally advantaged aircraft ice control materials involves two key elements: (1) identification of ice control material formulations which are inherently less damaging to the environment than current formulations; and, (2) development of efficient, high performance fluids which require less material to accomplish the objective of protecting aircraft surfaces from ice accretion. Foster-Miller is already pursuing the development of inherently environmentally advantaged freezing point depressants (FPD) in a U.S. Air Force Laboratory sponsored SBIR program. This SERDP sponsored project focuses on the development of anti-icing fluids, which will incorporate the FPDs developed under the SBIR program.

BENEFIT: The project benefits include: (1) a drop-in, fully characterized, environmentally advantaged replacement for ethylene and propylene glycol based aircraft deicing materials; (2) elimination of the cost of capture/treatment of effluent from aircraft deicing processes; (3) reduction of material cost for aircraft deicing processes (since high efficiency fluids require less material usage); and (4) increased flight safety and mission readiness. Additionally, this project will provide a model for non-Newtonian viscosity prediction based on the chemical structure of compounds and a model for predicting the impact of changes in ice control material formulation on runoff water quality at actual airfields.

ACCOMPLISHMENTS: The basic formulations (freezing point depressant, water, and thickener) have met Tier 1 and 2 test requirements, with the following exceptions: (1) a surfactant is needed to improve wetting, and (2) for some combinations of FPD's, a corrosion inhibitor may be required to meet appearance requirements of the corrosion test specification.

Biodegradable surfactants for the anti-icing and deicing fluid formulations were selected and evaluated. Surfactants were subjected to laboratory performance evaluations, biodegradability testing, toxicity literature review, and aquatic toxicity testing. Based on these results, two surfactants were selected for further testing. Newly emerging biodegradable surfactants are also being evaluated to determine if they offer improved performance. Eight anti-icer formulations containing FPD, water, thickener, and surfactant were submitted for holdover time and aerodynamic testing.

TRANSITION: All Services and the commercial airline industry will be apprized of initial results. Massachusetts STEP program is assisting in the coordination with stakeholders (FAA, Massport, EPA). Formal product qualification testing is being conducted by Octagon. Commercial airlines field test will be conducted after product qualification. ESTCP funded demonstration and validation at military base will be proposed.

PROJECT SUMMARY

PROJECT TITLE & ID: Sol-Gel Technology for Low VOC, Non-Chromated Adhesive & Sealant Applications; PP-1113

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. James Mazza; U.S. Air Force Research Laboratory – Wright Patterson Air Force Base, OH

FY 2001 FUNDS: $875K

DESCRIPTION: The primary objective is to eliminate the volatile organic compounds (VOC), chromates, and strong acids typically found in the metal surface treatment and priming steps conducted prior to application of adhesives and/or sealants. Secondary objectives are the reduction of hazardous wastewater streams associated with current processes and improved performance compared to these processes.

This project will develop, evaluate, and field demonstrate nonchromated, zero VOC sol-gel processes for adhesive and sealant applications. The sol-gel processes developed will replace the current approaches that are high-VOC and/or use chromates. They will also eliminate the current use of strong acids and reduce the waste streams associated with the existing processes. This project will build on recent work using sol-gel technology to deposit thin organic-inorganic coatings on metal surfaces to develop good adhesion between the metal and subsequently-applied polymers (primer, adhesive, or sealant) via covalent chemical bonding.

The tasks (three adhesive bonding and one sealant adhesion promoter/primer) are:

1. Find an environmentally friendly pretreatment/primer system that can be implemented in the near term by optimizing a sol-gel surface preparation that is compatible with experimental waterborne adhesive bond primers. This will be accomplished by sol chemistry optimization and by developing application procedures with emphasis on the surface activation drying/cure steps. Epoxy adhesives will be the primary focus, although polyamides may also be evaluated for titanium.

2. Develop a one-step process that combines the adhesive primer and sol-gel surface treatment into one consolidated interfacial layer. Findings regarding the important process variables identified in Task 1, such as surface activation for the various metal alloys, will be used to develop an application procedure. This approach will eliminate the need for a separate primer step.

3. Evaluate the sol/primer mixtures of Task 2 as traditional adhesive primers.

4. Leverage the sol-gel work for adhesive bonding to develop adhesion promoters for sealant operations. The highest priority area will be replacing the high-VOC primers used with silicone sealants with a zero-VOC sol-gel alternative. A second priority will be to develop a universal adhesion promoter for polysulfide and polythioether sealants to promote adhesion between these sealants and various substrates as well as adhesion between the two sealant types.

BENEFIT: Developing new nonchromated, zero-VOC adhesive and sealant surface preparation and primer technologies under this program will have a major impact on both cost and performance of military and commercial aircraft. Reductions in the use of hazardous materials and reductions in wastewater will be significant across the various DoD depot and field-level facilities. The new sol-gel processes are expected to provide increased bondline strength and/or durability for many applications; this will improve aircraft performance, decrease downtime and maintenance labor hours associated with reworking poor repairs, and enhance operational readiness.

ACCOMPLISHMENTS: In the development of processes for using sol-gel chemistry to prepare aluminum, titanium, and steel surfaces for structural adhesive bonding, testing indicates that the sol-gel approach will be acceptable for the repair environment important to the Services. At this time, best performance still requires the use of a chromated bond primer after surface treatment. Recent progress includes:

- Determined that the type of nongrit-blast abrasive greatly influences performance results as can the cure process (cocure or precure) of the subsequently applied primer. A plan was outlined to resolve these issues in FY01.

- Demonstrated the feasibility of using a laser to clean and deoxidize aluminum prior to sol-gel application. This would greatly reduce VOC usage associated with precleaning.

- Achieved promising results using a completely nonchromated process for certain low-temperature applications involving paste adhesives.

- Demonstrated the sol-gel process on B-52 aircraft and H-60 helicopters with input from the field that will guide optimization. The demonstrations show no insurmountable obstacles to field use.

- Generated initial process parameters data for aluminum bonding. These data are general performance tests that will then be employed by end-users as the starting point for qualification of the process for specific applications. Additional data, including fatigue test performance, were generated for grit-blast/sol-gel on Am 355 and 301 stainless steels. 1.2.

- Investigated the VOCs associated with the sol-gel chemistry. Although the sol-gel in this project is waterborne, a small amount of alcohol is generated during the chemical reaction. This was determined to be insignificant in tests conducted by AFRL/MLQ.

- Identified a commercial supplier to provide sol-gel kits, and began testing at the supplier's facility to optimize kitting procedures and supplement process parameters data.

Successful development of a one-step process appears to be the best chance to completely eliminate hexavalent chromium from the surface preparation process. Recent progress in this area includes:

- Evaluated sol-gel/primer mixtures; studies on aluminum substrates will continue.

- Focused hybrid work on low-temperature-curing systems (nonchromated) to fill a significant need for Navy and Air Force end-users bonding with paste adhesives.

- Development following two approaches, hybrid copolymerization and polymer blends/interpenetrating networks, shows promise.

- Developed a zero-VOC promoter that can work for multiple sealant types included the evaluation of sealant adhesion for both grit-blast and nongrit-blast processes. The bulk of the work focused on a grit-blast/sol-gel process for titanium substrates.

TRANSITION: Further testing at Navy Aviation Depots, Air Logistic Centers, and Army depots is anticipated after initial successes are demonstrated.

PROJECT SUMMARY

PROJECT TITLE & ID: Visual Cleaning Performance Indicators for Cleaning Verification; PP-1117

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Bruce Monzyk; Battelle – Columbus, OH

FY 2001 FUNDS: $156K

DESCRIPTION: The visual cleaning performance indicators (VCPI) are a combination of intense dyes and coupling agents (CA) that selectively attach to target contaminants on surfaces cleaned in Department of Defense (DoD) and Department of Energy (DOE) operations. This innovative technology promises to provide a widely-applicable, real-time, low-cost, quantitative/qualitative cleaning process monitoring technique. The implementation of such a technique will reduce hazardous and non-hazardous waste and processing cost by avoiding excessive as well as inadequate cleaning and by enhancing implementation of environmentally friendly cleaning alternatives.

The project consists of three tasks that will be carried out by Battelle in collaboration with Air Force Research Laboratory and Naval Surface Warfare Center-Carderock. In Task 1, the DoD partners will help identify target contaminants for large surface cleaning. Battelle will then select commercially-available CAs and dyes, that can attach to the target contaminants, using known science and with input from DoD partners on material compatibility. The Task 2 consists of feasibility testing of the VCPI concept. The DoD partners will prepare coupons for testing and Battelle will source the contaminant CAs and dyes. In the Task 3, Battelle will clean the VCPI-treated contaminated coupons to demonstrate a relationship between color intensity and residual contaminant level. The DoD partners on the other hand will perform application-specific cleaning to determine whether VCPI components are compatible with DoD cleaning operations and materials of construction.

BENEFIT: This innovative technology promises to provide a widely-applicable, real-time, low-cost, quantitative/qualitative cleaning process monitoring technique. The implementation of such a technique will reduce hazardous and non-hazardous waste and processing cost by avoiding excessive as well as inadequate cleaning and by enhancing implementation of environmentally friendly cleaning alternatives.

ACCOMPLISHMENTS: The team identified target contaminants and cleanup processes of importance to Air Force and Navy. The long list of contaminants of concern were grouped into a few physical/chemical classes, each class of which can use a common VCPI system. A large number of coupling agents (CA) and compatible dyes were identified which were down-selected to at least two dye-CA candidates each (primary and backup) for labeling each class of contaminants. In feasibility testing of the concept, results to date indicate that the best applications for VCPI appear to be those where the contaminant is fully cleaned off/out of the surface during the normal cleaning operation. Otherwise, residual VCPI dye remains with the residual contaminant resulting in a residual dye color on the surface and an unacceptable surface finish.

The most difficult surfaces and contaminants to clean are painted surfaces contaminated with oil or grease. In these cases, only low levels of dye can be used, if the VCPI method is used at all for these systems, since residual contaminant within the paint is acceptable for the finished cleaning process. Far better applications for hydrophobic contaminants appear to be those involving substrates of bare metal, though painted steel may still qualify according to preliminary results from tests in progress. In these cases, the dye readily informs the cleaning operator where cleaning is still needed. Other promising contaminants for the VCPI technique appear to be corrosive soluble salts and metal corrosion products. Detailed systemic cleaning tests are still in progress to quantify results and rank various DoD applications.

TRANSITION: Working with DoD/DOE Depots, Battelle will field test the technique, specifically for aircraft cleaning, application of tiles and painting of shipboard surfaces, and application to critical cleaning for weapons manufacture and demilitarization.

PROJECT SUMMARY

PROJECT TITLE & ID: Supercritical Fluid Spray Application Process for Adhesives and Primers; PP-1118

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Marc Donohue; Johns Hopkins University – Baltimore, MD

FY 2001 FUNDS: $382K

DESCRIPTION: The project objective is to investigate and develop low/no-volatile organic compound (VOC), non-structural adhesives to substitute for the current high-VOC, non-structural adhesives used in military applications. It is estimated that 8.5 billion pounds of synthetic polymer adhesives are used annually, of which approximately 55 percent are VOCs. While the total DoD usage is not known, it is estimated that approximately 173,000 pounds of VOCs are released annually by Air Force aircraft operations. VOCs commonly used in applying adhesives include aromatics (e.g., toluene), ketones (e.g., acetone, methyl ethyl ketone), and others (e.g., methanol, chloroform). They are ozone depleting substances which negatively impact worker health, safety, and environment. Environmental standards for these substances require hazardous material management including cost of permits and emission control equipment.

Conceptually, the UNICARB process is straightforward in that a concentrated solution of polymeric material (in this case the adhesive and adhesive primers), and other additives are mixed in situ with high-pressure (in the range of 1000 psi to 2000 psi) carbon dioxide and then sprayed. In practice, the process is complicated in that one is mixing an incompressible, highly viscous material (polymeric material and solvents) with a highly compressible fluid of very low viscosity (supercritical carbon dioxide). The solvents are mixtures of fast and slow evaporating VOCs which are chosen specifically for their ability to dissolve the polymeric material, reduce viscosity, and aid in atomization and droplet coalescence on the substrate. In the supercritical spray process, supercritical carbon dioxide replaces that fraction of the organic solvent that is needed to give the viscosity reduction necessary for spray atomization. This is also the solvent that is the primary contributor to the high VOC emissions.

This project will adapt the UNICARB spray application process to adhesives in two ways: (1) a continuous process for use in a manufacturing setting, and (2) a portable hand held batch process for use in small jobs or repair scenarios. Each of these processes requires its own unique set of phase diagrams given that the portable device operates in dynamic conditions (the materials and pressures of the system are changing with time), whereas the continuous spray operation operates in a steady state mode (the system pressure and material compositions remain constant with time). Therefore, for each adhesive adapted to the UNICARB process, two different types of phase diagrams will need to be generated.

The goals of this 4-year project are to adapt six non-structural adhesives to both a continuous and portable UNICARB process. The following approach will be taken:

- The polymeric material and solvent constituents of the six adhesives will be evaluated for their compatibility to the process.

- The identity and proportion of the various high and low volatile solvent constituents comprising the present adhesive mixture will be determined.

- Once the phase behavior is determined the configuration of the batch and continuous process will be established and tested.

- Based on the above tests, formulation of the supercritical carbon dioxide-solvent-polymer mixture will be further investigated for optimization of performance properties and minimization of environmental impacts.

- After determination of the optimal adhesive formulations, both processes will be field tested on various applications at venues to be determined by the respective military collaborators for this project.

- For each adhesive that is reformulated and adapted to the UNICARB process, a concurrent effort will be made to develop the underlying thermodynamic and rheological behavior.

BENEFIT: The principle cost benefits of this project will be from reformulation of existing adhesives now used by the military, and reduction in environmental impacts associated with the VOCs. By re-engineering the UNICARB process to one that can be applied with a hand-held device, the military will be able to increase the number of applications and venues where environmental compliance can be achieved. The advantages of adopting this process include: reduction in VOC emissions; reduction in solvent costs; use of existing and proven adhesives and primers; more evenly distributed coatings; reduction in labor costs; reduction of worker health and safety costs; and, reduction of costs associated with hazardous material management respective to permits and emission control equipment.

ACCOMPLISHMENTS: The examination of the neoprene system was completed. Our results for the neoprene system with 25% carbon dioxide show a 300 to 400 psi difference between the lower static and higher dynamic results. This is seen from 40C to 70C. The analysis of the acrylic system that was performed initially has been reinitiated. Similar behavior was observed for the acrylic system to that seen in the neoprene system. The automation of the data acquisition process was completed by including an automated piston controller and modifying the automated data collection computer. These changes will make it possible to increase our testing speed and accuracy by limiting the opportunity for human error.

TRANSITION: DoD participants are the Tank Automotive & Armaments Command and Aviation & Missile Command. The investigator plans to work with adhesive manufacturers and equipment companies.

PROJECT SUMMARY

PROJECT TITLE & ID: Critical Factors for the Transition from Chromate to Chromate Free Corrosion Protection; PP-1119

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Rudolph Buchheit; Ohio State University – Columbus, OH

FY 2001 FUNDS: $490K

DESCRIPTION: The overall goal is to acquire a fundamental understanding of the chemical and physical processes and mechanisms of corrosion protection by chromate-based coatings applied to metal surfaces with a specific focus on corrosion protection of aluminum alloys. This project comprises a four year fundamental research effort. Specific objectives are to: (1) define a set of phenomenological and fundamental rules that describe the role of microstructural heterogeneity in chromate conversion coating formation and breakdown; (2) define the relationship between chromate conversion coating structure and chemistry, and coating properties for coatings applied under non-ideal conditions such as those that exist during coating applications in manufacturing and military maintenance depot environments; (3) determine the extent to which application method, coating age, and alloy substrate chemistry affect the self-healing nature of chromate coatings; and (4) develop rapid, quantitative, and predictive tests to assess properties and performance of chromate conversion coatings.

BENEFIT: Chromate corrosion protection technologies are expensive to operate and generate much hazardous waste. The expected benefit of this research is an increased fundamental understanding of the mechanisms of corrosion protection by chromate-based coatings. Ultimately, this information will support the development of effective chromate-free alternatives.

ACCOMPLISHMENTS: Selected accomplishments include: microstructural and chemical characterization of aluminum armor alloys 2519, 5083, and 7039. A specially designed, small length scale electrochemical cell has been constructed to support intermetallic compound (IMC) studies. Two new studies focusing on the effect of variable copper concentration on chromate conversion coating (CCC) formation on 7XXX alloys, and the effect of aging on CCC properties have been completed.

TRANSITION: All Services and DoD partners will be apprised of initial results from this fundamental research and will be used to aid in modifying procedures and specifications for corrosion protection by coatings.

PROJECT SUMMARY

PROJECT TITLE & ID: Mechanisms of Military Coatings Degradation; PP-1133

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Steven McKnight; U.S. Army Research Laboratory – Aberdeen Proving Ground, MD

FY 2001 FUNDS: $1000K

DESCRIPTION: Military coating systems are usually repainted for the following reasons: loss of appearance (aesthetics, camouflage, cleanliness); chipping, peeling, debonding of the coating; and corrosion of the substrate. The primary technical objective of this project is to identify, model, and predict degradation mechanisms that lead to military coating system failures, which require depaint and paint operations over the life of the weapon system. An overall deliverable of the proposed effort would be pollution prevention via intelligent reduction of the paint/repaint frequency. The project is developing models of coating degradation and providing a scientific basis to develop new durable coating formulations that will help to achieve this goal. The complexity of the problem demands complementary studies to fully understand the degradation mechanisms. This project will investigate mechanisms of military coatings degradation used on aircraft (Navy), combat ground vehicles (Army, Marines), and support equipment (Navy, Army, and Marines). The primary focus will be on the primer/topcoat systems that are being fielded to comply with environmental legislation and regulations. Both accelerated tests as well as static and dynamic field conditioning to assess coatings degradation in military systems and environments will be investigated. Most prior coatings degradation work has focused on commercial systems and has attempted to relate accelerated lab tests to actual service conditions. The response of any coating system to the environment is complicated and depends on resin type, pigment-resin, primer-topcoat, and primer-substrate interactions. Each element must be addressed to fully understand the degradation mechanisms of the coating system as a whole.

BENEFIT: The end result of this project will be an understanding of the mechanisms that explain the degradation of organic coating systems when exposed to military type environments. These mechanisms will be modeled and included in a statistical method for accurately predicting the performance of coating systems. Furthermore, an extensive database is being produced and shared with DoD, industry, and academia that documents results from accelerated aging, static weathering, and dynamic weathering of the new water-reducible coatings systems that are targeted for insertion in the near future. A thorough and quantified understanding of the mechanisms of coatings degradation will promote further confidence in environmentally friendly coatings and thereby increase acceptance of these new systems. Improved confidence will result in faster implementation of the low VOC coatings on military platforms.

ACCOMPLISHMENTS: Recent results have demonstrated that environmentally friendly coatings may actually out perform solvent based systems in terms of durability. A mechanism for UV induced degradation of the polymer binder has been identified and kinetic models are being evaluated. Research has yielded useful data concerning the effect of UV exposure on moisture transport that may affect initial corrosion resistance after UV exposure. The data were used to validate the two phase Fickian diffusion model that has been developed to predict the concentration of moisture in the primer/topcoat system at any given time. The model continues to show good agreement with experiment and shows that predictive modeling can be used in certain instances. New work has shown the influence of increased topcoat diffusion on the system performance. The model was able to capture these effects, and showed that the primer properties are even more critical after the topcoat has degraded due to exposure to UV. This work has been published in a series of Army tech reports as well as technical briefings.

TRANSITION: The results and models will be transitioned by promoting their use, as bases for defining performance criteria, and in the contracts issued during the acquisition (or rebuild) process. Additionally, the models can be incorporated into materials specifications and/or manuals as criteria for qualification or use. Finally, standardization and industry acceptance of such models would be pursued using existing work groups and through existing relationships with materials suppliers.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Innovative Nondestruction Evaluation (NDE) Technologies for the Inspection of Cracking and Corrosion under Coatings; PP-1134

PRINCIPAL INVESTIGATOR & ORGANIZATION: Ms. Michele Novack; U.S. Naval Surface Warfare Center, Carderock Division – West Bethesda, MD

FY 2000 COMPLETED PROJECT

DESCRIPTION: The objective of this program was to develop and evaluate three technologies for their viability as nondestruction evaluation (NDE) tools for the detection of cracks and corrosion under surface coatings in aircraft and ground vehicle applications. They have been developed in the private sector under either private or SBIR program funding and have shown promise for meeting the technical and sometimes unique logistical needs of DoD aircraft and ground vehicle applications. These technologies include: (1) Ultrasound Imaging, (2) Thermal Imaging, and (3) Near-Field Microwave Imaging. These technologies were proposed for investigation based on their potential to inspect areas rather than points (translating into efficient levels of inspection scan rates), portability to the job site, overall projected economy to implement, and relative technology maturity. Two of the techniques, Ultrasound and Microwave Imaging, are believed to be effective in detecting cracks under coatings and were investigated for that purpose, as well. In parallel to NDE techniques development, models were developed to correlate with the output signature of these various techniques. Electrochemical Impedance Spectroscopy (EIS) was used to validate the measurements. Finally, a "roundrobin" test was performed to determine the most effective NDE technique for detecting corrosion.

BENEFIT: Conventionally, the problems of corrosion (chemical degradation) and fatigue cracking (mechanical degradation) have been addressed through the application of surface coatings and NDE inspections (e.g., eddy current or magnetic particle methods). These practices remain a significant portion of the maintenance budget for each system and play a major factor in overall system readiness especially since the conventional NDE methods require the removal of surface coatings in order to conduct interrogations of the metallic substrate. According to a recent estimate, the ability to detect and repair corrosion areas prior to severe degradation will reduce operational maintenance cost by 25 percent and will improve operational readiness.

ACCOMPLISHMENTS: Naval Air Warfare Center (NAWC), in collaboration with Imperium, Inc., designed, built, and conducted basic laboratory evaluation of a single-side ultrasonic imaging system. NAWC also completed modeling work on the active thermographic technology and coordinated the complementary work being performed at Thermal Wave Imaging, Inc. and Wayne State University. The microwave technology projects at Texas Research Institute, Austin and Colorado State University have completed and shown the capability to reliably detect cracks and corrosion through surface coatings. Both the ultrasonic imaging and the active thermographic technologies have received interest from NAVAIR program offices for potential transition. Technical presentations have been made and the associated papers published in technical journals.

TRANSITION: All Navy Ship Systems experimentation stations will be apprised of the results from this program for actual in-service field trials. Additionally, some technologies may prove to be mature enough for transition to commercial development will be pursued.

PROJECT SUMMARY

PROJECT TITLE & ID: Primerless RTV Silicone Sealants/Adhesives; PP-1135

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Dean Martinelli; U.S. Army, TACOM-ARDEC – Picatinny Arsenal, NJ

FY 2001 FUNDS: $290K

DESCRIPTION: Room temperature vulcanizing (RTV) silicones, developed in the late 1940's, have played an important role in the design and superior performance of weapon systems (airplanes, missiles, electronics, ammunition, vehicles and nuclear weapons) developed by the DoD and DOE. A unique combination of properties has made them the material-of-choice for designers wanting to improve and increase weapon performance. RTV silicones are used as adhesives, sealants, coatings, heat insulators and encapsulating materials. For RTV silicones to achieve a high level of consistent adhesion to various substrates, a saline primer is applied prior to silicone application. These primers contain 90-98% volatile organic compound (VOC) solvents, which evaporate into the air. The objective of this project is to develop, evaluate, and transition a primerless self- bonding low temperature curable addition cured silicone, which eliminates the use of high VOC primers without compromising durability, compatibility, thermal resistance and long term stability. The technical approach includes four phases. In phase I, current addition cured silicones available off the shelf will be modified with a bifunctional adhesion promoter compound. In phase II, a less inhibiting adhesion promoter, based on structures defined by molecular modeling will be utilized in an attempt to develop room temperature curing systems. Laboratory adhesion evaluations will be used to establish "go/no go" criteria for technology development in phase II. To expand adhesion capability to a variety of substrate materials, including plastics, novel adhesion promoting concepts will be evaluated in phase III using guidance from molecular modeling predictions. Phase IV will demonstrate the use of a new primerless silicone formulation.

BENEFIT: This technology will eliminate traditional primers leading to a reduction of over 500,000 lb/yr of VOCs; avoidance of costs from waivers, deviations and fines associated with the use of non-compliant materials; savings derived from reduced hazardous waste disposal costs; improvement of throughput; reduction in inventory management costs; and cost savings from reduced purchasing, material handling and specification consolidation.

ACCOMPLISHMENTS: First-generation elevated temperature curing formulations have been developed and validated by DoD/DOE labs. Baseline studies for the second-generation room temperature curing formulations were conducted and several second-generation adhesion-promoters were synthesized and screened. A best candidate second generation formulation was down selected and optimized. Successful validation of these formulations have been completed by Army and DOE labs. Validation of second generation formulations meeting Air Force and Navy requirements are ongoing. Substrate materials for third-generation formulations were finalized and third generation adhesion promoter development for novel substrates were initiated.

TRANSITION: The transition of this technology will occur through revision of military specifications (MIL-A-46106, etc.) and by modification of current data packages with engineering change proposals.

PROJECT SUMMARY

PROJECT TITLE & ID: Nondestructive Testing of Corrosion under Coatings; PP-1137

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. John Weir; Northrup Grumman Corporation – Bethpage NY

FY 2001 FUNDS: $440K

DESCRIPTION: Aircraft painting and repainting operations result in significant emissions of volatile organics, organic and inorganic hazardous air pollutants, and hazardous waste. Aircraft paints are routinely removed to reveal the presence of corrosion on the surface of metal structures and the aircraft is subsequently repainted. Surface corrosion on aluminum aircraft skins and around joints and fasteners is often the precursor to buried corrosion. The objective of this project is to develop nondestructive inspection techniques to detect the presence of corrosion under an organic film in order to reduce the amount of painting and depainting that is performed. This project will develop: (1) a spectral NDE technique employing an optical reflectance probe in the near/mid IR region combined with Directional Hemispherical Reflectance (DHR) and Fouier transform infrared reflectance (FTIR) integrated detector; (2) Wide-area spectral imaging (WASI) using spectral filters and high-resolution focal plane cameras to allow rapid initial assessment of sub-paint corrosion; and (3) a Scanning Kelvin Probe (SKP) electrochemical method employing a calibrated capacitance probe to indirectly measure corrosion potential across a surface. These inspection and measurement techniques will be used to target and map specific areas that require maintenance due to corrosion, thus eliminating the need to completely strip and reapply the exterior coatings. Challenges to be overcome include probe positioning and electrical noise. The technical approach includes five major tasks: (1) baseline measurements of unexposed coatings and typical corrosion products to build up a database of standards; (2) evaluation of aged aircraft components; (3) optimization of measuring systems at varying levels of corrosion and their modification for field use; (4) prototype verification (in conjunction with NAWCAD); and (5) preparation of a transition plan for cost-effective applications.

BENEFIT: Minimizing the number of times the aircraft exterior coatings are stripped and reapplied provides substantial pollution prevention and cost saving opportunities. The inspection and measurement techniques provide a means to verify the condition of coating thus allowing for a switch to a condition-based rather than schedule-based maintenance and to verify the condition of the primer and surface preparation once the topcoat has been removed thus eliminating a portion of the rework that now routinely occurs.

ACCOMPLISHMENTS: Free-standing paint films were prepared for the following coatings: MIL-P-85582, TT-P-2760, MIL-C-85285, and MIL-S-81733 over the range of 1 to 10 mils. Using the IR imaging technique, the directional hemispherical reflectance of the free-standing films was determined. Overall it was shown that very low levels of substrate corrosion could be imaged through these stand alone coatings. The next phase of the test program will require application of the various coating systems to the corroded substrate to ascertain if the corrosion is detectable at these low levels.

Electrochemical techniques investigated include localized impedance spectroscopy, conventional Volta potential measurements with a Kelvin probe and Volta potential measurements in ionized air. Using the Kelvin probe and impedance techniques, the project demonstrated the ability to detect a corroded localized area under 3.4 mils of paint.

TRANSITION: Weapon systems will be identified that can use the spectral imaging and electrochemical measurement technologies to assess the condition of underlying substrates relative to corrosion without coatings removal.

PROJECT SUMMARY

PROJECT TITLE & ID: Cleaning Verification Techniques Based on Infrared Optical Methods; PP-1138

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. David Otteson; U.S. Department of Energy, Sandia National Laboratory – Albuquerque, NM

FY 2001 FUNDS: $485K

DESCRIPTION: The objective of this project is to develop a real-time method to provide both qualitative and quantitative assessments of surface cleanliness for a wide variety of military cleaning applications. The introduction of new environmentally acceptable solvents for traditional chlorinated hydrocarbon materials has produced major uncertainties in standard cleaning procedures. As a result, many applications overutilize solvents to ensure component cleanliness and the success of any subsequent processing operations (such as coating or bonding). This, in turn, leads to the additional usage, handling and disposal of hazardous materials, while also wasting personnel operating time. This project will develop two prototype infrared-optical instruments with complementary capabilities for use at DoD sites that will reduce the use, emission and handling of hazardous materials in cleaning operations, and will also be applicable to DOE and commercial sector needs. Currently, the detection of surface contamination on reflective surfaces is most convenient and rapidly done by the Fourier transform infrared reflectance (FTIR) method which provides both quantitative and qualitative information on surface coatings. Specifically, the project will: (1) develop a prototype on-line widely tunable infrared laser based instrument with high speed surface-imaging capability but with limitations on the number of detectable organic contaminants; and (2) optimize an FTIR based instrument with high sensitivity for organic species on a variety of surfaces, but with limitations on speed and surface coverage for real-time analysis of surface contaminants at very low level of concentrations. The proposed instruments will differ in the nature of the information they provide. The first will produce images that directly indicate the spatial extent and location of contamination. The second will provide a spectrally-resolved measurement of the surface reflectance at a single point.

BENEFIT: This project will develop two infrared optical methods that address the need for new surface cleanliness analysis technologies and will benefit DoD operations in several ways. The methods will be able to: (1) operate in real-time and will be useful in process monitoring and control; (2) provide qualitative and quantitative output for comparative assessment of cleanliness levels (both quantitative amounts and species present); (3) handle a wide variety of military specific applications, such as repair and remanufacturing processes at repair depots; and (4) measure cleanliness levels such that they can be related to required materials property requirements for various surface preparation processes (e.g., repair or application of protective coatings).

ACCOMPLISHMENTS: Continued development of FTIR spectroscopy and tunable infrared- laser imaging as real-time methods for the detection of contaminant residues common to DoD components. A series of calibrated test panels were evaluated with both optical methods. A prototype FTIR instrument was designed, fabricated, tested, and now commercially available. A successful field demonstration was conducted at NAVDEP, North Island, San Diego, CA. A preliminary cost-benefit analysis for the infrared optical techniques was also conducted with an estimated payback for a single application of 2.3 years.

TRANSITION: Transition to both research and development organizations and DoD end users will be integrated over the life of the project through field testing at DoD facilities, communicating the results to DoD and DOE users, and aggressive pursuit of commercialization.

PROJECT SUMMARY

PROJECT TITLE & ID: Non-Structural Adhesives Requiring No VOCs; PP-1139

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Claude Selitrennikoff; MycoLogics – Denver, CO

FY 2001 FUNDS: $183K

DESCRIPTION: Currently available adhesives include epoxy-polyamides, polyurethanes, organo-silanes, cyanoacrylates and polyvinyl acetates. These often require toxic volatile organic compounds (VOCs). Commonly used VOCs include toluene, methylethylketone, acetone and xylene. In sunlight, VOCs and nitrogen oxides produce ozone. Other VOC interactions contribute to the formation of photochemical smog. Non-VOC adhesives would substantially reduce this form of air pollution. The search for strong, environmentally compatible adhesives has turned to such examples in nature as the tenacious adherence of barnacles and mussels to rocks. Although the properties have indeed been spectacular, production of these adhesives on a commercial scale is problematic. The objective of this project is to use microorganisms as a source of novel adhesives which do not include any toxic VOCs. These natural compounds will be environmentally safe yet still meet physical property performance requirements for numerous DoD applications.

BENEFIT: The Army, Navy and Air Force use non-structural adhesives for gaskets, instrument panels, textiles, packaging and labeling. Medical applications include biocompatible tissue augmentation, wound closure and drug delivery systems. DoD will realize significant cost savings from compliance with environmental regulations and the decrease in medical costs associated with the use of VOCs.

ACCOMPLISHMENTS: Three hundred (300) microorganisms were screened for production of adhesive compounds. Crude adhesive materials were tested by flatwise tension using bare aluminum 2024. Fatty acid and DNA analyses were performed on selected organisms to ensure no duplicates were included in the group downselected for shear and peel testing.

A constant force fixture was designed and constructed to hold bolts together at a constant, calibrated force to provide a standardized thickness of the adhesive.

A defined medium was developed to replace the complex medium used during initial screening. This significantly simplifies the attenuated total reflectance Fourier transform infrared reflectance (ATR-FTIR) and Time of Flight Secondary Ion Mass Spectroscopy (ToF-SIMS) testing and contributes to making large scale production economically viable.

TRANSITION: A transition team meeting provided valuable input to help ensure the objective adhesives will be useful to DoD. The adhesives will be tested to qualify them for Army, Navy, Air Force and DOE application as well as for use in the private sector.

PROJECT SUMMARY

PROJECT TITLE & ID: Electro-Spark Deposited Coatings for Replacement of Chrome Electroplating; PP-1147

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Joseph Argento; U.S. Army Armament Research, Development, and Engineering Center – Picatinny Arsenal, NJ

FY 2001 FUNDS: $547K

DESCRIPTION: Chrome electroplating is one of the most widely used surface treatment processes throughout the military services. The current alternative technologies such as high velocity oxygen fuel (HVOF) process are gradually replacing chrome electroplating for some applications. However, there currently exists a need for alternate technologies where alternate technologies such as HVOF coatings cannot be applied. In recent years, electro-spark deposition (ESD), a novel coating technology has been developed that produces some of the most robust, damage-resistant coatings known. ESD is a pulsed-arc, micro-welding process that uses short-duration, high-current electrical pulses to deposit, with very low heat-input, a consumable electrode material on a metallic substrate. The short duration of the electrical pulse produces very rapid solidification of the deposited material resulting in a nano-structured coating demonstrating unique wear and corrosion performance. The process releases no hazardous wastes, fumes or effluents, is cost-effective, requires no special chambers, spray booths or operator protection, and eliminates the hydrogen embrittlement problems that can occur with some substrates. Unlike some of the alternate technologies which may produce mechanical or chemical bond, the ESD technology creates a true metallurgical bond while maintaining the substrate at ambient temperatures. The objective of this project is to develop process control sensors, process parameters, equipment, and techniques using ESD to coat inside diameters and other difficult geometries with robust wear and corrosion-resistant coatings that will replace current chromium electroplating applications. The technical approach consists of developing the process parameters for selected material coatings required for specific military applications, and the process control sensors and algorithms necessary to achieve those parameters in non-line-of-sight applications. Power supply modifications and automated control devices will be developed and used to apply coatings to representative components for each military service. The components will be tested as part of the process optimization efforts, using specific test conditions defined by the military services.

BENEFIT: This will complement current replacement technologies, such as HVOF, by allowing coating of non-line-of-sight geometries that HVOF and other thermal-spay processes cannot coat. Cost benefits include: low capital expense (approximately $30K) compared to new Cr-plating lines (greater than $1 million) or HVOF (greater than $400K); elimination of waste disposal costs, $0 for ESD compared to greater than $10 million per year reported for Cr-plating for the Army alone; reduced or eliminated surface preparation costs relative to either Cr-plating or HVOF processes; and savings from portability of process to allow use in field or shipboard to coat or repair components in-place, with minimum set-up.

ACCOMPLISHMENTS: Two coating materials were chosen for their good deposition characteristics and their demonstrated potential for replacement of chromium repair of military components. Efforts in FY01 will focus on the development of process controls and sensors for automated ESD.

TRANSITION: This project will generate a working prototype of ESD system for non line-of-sight (NLOS) surface coatings, and protocols for process testing. Results of the process tests for the military Services will be reported to team members and to the technical community at the DoD Hard Chrome Alternatives Team (HCAT).

PROJECT SUMMARY

PROJECT TITLE & ID: Novel Conductive Polymers as Environmentally Compliant Coatings for Corrosion Control; PP-1148

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Peter Karras; Naval Air Warfare Center – China Lake, CA

FY 2001 FUNDS: $500K

DESCRIPTION: Corrosion prevention using new conductive polymer (CP) coating materials will be the focus of this project. Environmentally compliant formulations combined with a benign process for the application of these coatings will provide the DoD community with an attractive alternative to current chromate-containing coatings. For years the chromate-containing coatings have been used to treat aluminum alloys such as 7075-T6, 7075-T3 and 2024-T3. Many DoD platforms such as the F-18, F-16, F-22, Joint Strike Fighter, MV-22, CV-22, H-60, C-141, C-130, C-5, and P-3 Orion aircraft use these chromium treated alloys. Hexavalent chromium (Cr^{+6}) has been identified as a health threat, and because of its toxicity, is currently highly regulated. New EPA regulations governing air emissions and lower OSHA permissible exposure limits (PEL) have greatly reduce the levels of Cr^{+6} allowed to be discharged into the industrial environment where workers will risk exposure to this known carcinogen. Therefore, chromate-free coatings are needed that also exhibit equal or superior corrosion protection. Conductive polymer coatings provide such an opportunity to reduce these hazardous materials, eliminate Cr^{+6} from coating formulations, allow compliance with new environmental regulations, and reduce hazardous disposal costs while ensuring mission readiness and worker safety. Several key steps to demonstrate the concept are:

Preparation of CP Powders: The first phase of this study is to prepare kilogram quantities of demonstrated BAM-PPV materials at NAWCWD, China Lake, CA. Concurrent with this effort will be the preparation of 10-gram quantities of oligoaniline acrylate polymer (OAP) by Rensselaer Polytechnic Institute (RPI) at Troy, NY. The NAWCWD-prepared BAM-PPV has been well characterized and has shown conclusive evidence of corrosion inhibition from constant current (galvanostatic) and constant potential (potentiostatic) measurements. These electro-chemical studies were conducted in concentrated salt-water solutions and provided quantitative evidence in reducing the pitting corrosion of aluminum alloys. The procedure for scaling up these CP materials has been successfully demonstrated at the 200-gram scale in moderate yield and high purity. Scale-up to kilogram quantities will proceed using the same procedure. Purity will be demonstrated by the same characterization techniques as previously used for the multi-gram batches (NMR and DSC). One small batch of the water-borne polymer, WAM-PPV, has been prepared, hence there is risk in scale-up, however, no difficulties are anticipated. RPI will prepare multi-gram quantities of OAP. Copolymers will be prepared with monomers used in the paint industry such as butyl acrylate, methyl methacrylate, and ethyl hexyl acrylate. This synthetic effort will focus on control of the Mw of polymer to allow easy processability during coating applications.

Paint Formulations with BAM-PPV and Benign Applications of these Materials: CP will be prepared for use in three different chromate-free formulations/processes. Water-borne paint/primer formulations (using water-soluble polymers or water-emulsified polymers) will be coated onto aluminum alloy substrates 7075-T6, 7075-T3, and 2024-T3. BAM-PPV materials will be dissolved/dispersed in liquid CO_2 formulations and coated on the same coupons at NAWCWD. (OAP will not be formulated pending corrosion testing of the neat material.) BAM-PPV materials will be used in powder-coating formulations developed at NAWCWD and coated onto these coupons by the Naval Aviation Depot, (NADEP) Jacksonville, FL using their spray booths. These three processes eliminate all solvent VOC content. Some CP coatings will also have a topcoat, such as MIL-C-27725 (translucent polyurethane topcoat), to compare with current coatings.

BENEFIT: The expected payoff is fourfold: (1) increased environmental safety by reducing toxic metals; (2) increased endurance of military equipment subject to corrosion conditions (humidity, seawater, and salt spray); (3) increased mission readiness; and (4) significant cost savings by reducing painting/depainting waste treatment.

ACCOMPLISHMENTS: To reduce the number of steps, a three-step synthesis was devised. The first step relied on new catalyst technology enabling an aryl halide to be coupled to an alkyl amine. The catalyst and required ligand are now commercially available and the starting aryl halide is inexpensive. The material can be synthesized in a 77% yield with only trace quantities of the mono-substituted compound. The second step involved the selective chlorination at the two benzylic sites. A number of methods are possible and there are ongoing experiments to determine the most feasible. The third step will be the standard PPV synthesis already used for the current BAM-PPV synthesis. The final synthesis step in the scale-up process has been completed and 200g of polymer obtained.

TRANSITION: This approach is based on a tight feedback loop between industry and end-users to provide a fast-track approach to product development for fleet-wide use.

PROJECT SUMMARY

PROJECT TITLE & ID: Computational Design of Corrosion Resistant Steels for Structural Applications in Aircraft; PP-1149 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Charles Kuehmann; QuesTek Innovations LLC – Evanston, IL

FY 2000 COMPLETED PROJECT

DESCRIPTION: The program's objectives are to design, prototype, and characterize a new corrosion resistant steel that can significantly reduce DoD's use of cadmium during rework, maintenance, and the manufacturing of structural steel components for aerospace applications. The new steel was developed by applying advanced computational tools, models, and design methodology, establishing the suitability of the new method to develop alternative processing paths and materials to replace existing processes and materials that pose increasing environmental concerns. Dynamic models were used to predict evolution of microstructure in both processing and service. There are four primary technical Tasks within the program. The specific activities within each Task result from the application of *Materials by Design* approach, which integrates processing, structure, property, and performance relations within a multilevel systems structure. The first task, Analysis, generated a systems flow-block diagram and calibrated models for the design process. The second task, the Design/Synthesis Task, determined an alloy composition and processing variables from the design criteria. During the third task a 300 lb. heat of the prototype material was acquired and characterized; and during the final task, a technical report was prepared detailing the program activities and analyzing the feasibility of the alloy design and its potential for further development and commercialization. A prototype of an entirely new corrosion resistant steel was delivered possessing similar mechanical properties to those of 300M and compatible with current and emerging aerospace coating processes such as high-velocity oxygen fuel (HVOF) technology.

BENEFIT: The benefits of mechanistic computational design technology is that it is now possible to rapidly develop entirely new materials and processes at costs that are orders of magnitude below the historical application of "trial and error" methods. The new steel developed promises to eliminate cadmium at DoD manufacturing and overhaul and repair facilities.

ACCOMPLISHMENTS: A secondary hardening stainless steel has been designed using computational materials design methods with the goal to provide a mechanical equivalent to 300M that eliminates the requirement for cadmium coating, and with it eliminates the primary failure mechanism for today's aircraft landing gear. The alloy, a high Co-Ni-Cr, M_2C strengthened martensitic steel, met the primary objectives for ductility and corrosion resistance, but was 15% low in strength. The strength deficit was due to an improper heat treatment during the forging of the prototype at the mill.

TRANSITION: QuesTek is working to develop joint venture agreements with alloy producers and landing gear manufacturers to be executed once the proof of concept has been established. The specifications for the proposed alloy and the protocol for material testing and evaluation have been designed to meet the end-user standards of Boeing and BFGoodrich in the U.S., and of Messier-Dowty in Canada.

PROJECT SUMMARY

PROJECT TITLE & ID: Electrodeposited Mn-Sn-X Alloys for Corrosion Protection Coatings; PP-1150 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Giovanni Zangari; University of Alabama – Tuscaloosa, AL

FY 2000 COMPLETED PROJECT

DESCRIPTION: Electroplated cadmium (Cd) finds numerous applications in defense finishing requirements, such as coatings providing corrosion protection, low coefficient of friction and/or solderability. However, Cd as a metal and Cd processing are extremely toxic to the environment and to humans, and its release is strictly controlled both by EPA and OSHA. Environmental concerns have triggered initiatives towards the substitution of Cd with environmentally benign materials and production processes. This project seeks to develop novel, low cost and environmentally benign electrodeposition processes for the production of alloy coatings based on manganese (Mn) and/or zinc (Zn) which combine high corrosion protection performance, good wear behavior and suitable mechanical properties, thus constituting realistic alternatives to Cd. Processes for the synthesis of Mn-Sn-X and Zn-based alloy coatings are being developed in parallel, and the coatings are characterized and thoroughly tested. Optimization of coating composition and codeposition of lubricating or hard particles are employed to optimize corrosion resistance and wear properties of the coatings. This research is anticipated to provide preferred embodiments for the production of suitable substitutes to Cd coatings with low environmental impact, and an extensive array of data on the properties of Mn- and Zn-based alloys as possible substitutes for Cd. The potential transition to a new technology would be facilitated by the use of electrodeposition processes, as the necessary innovation in processing lines would be minimized.

BENEFIT: If fundamental technical difficulties associated with the development of a new process are overcome, this project is anticipated to lead to a preferred electrodeposition process with low environmental impact for the production of corrosion protection coatings that would be effective general substitutes of cadmium coatings in defense applications. The extent of innovation and of the environmental/economic benefits to be reaped from the results of this project are critically dependent on technical issues, but a fully successful outcome holds the promise to revolutionize the current approaches and environmental consequences related to the production of corrosion protection coatings to defense and a number of civil applications.

ACCOMPLISHMENTS: Various environmentally benign chemistries have been identified and investigated for the electrodeposition of the pure metals and the alloy. The structural properties and corrosion resistance of pure Mn and Sn-Mn alloys from ammonium sulfate and methansulfonate electrolytes were studied in detail. At high current densities, pure Mn coatings are black and shiny; the crystalline structure is amorphous and stable in time. The corrosion resistance of the amorphous structure in borate and chloride environments is much higher. For Sn-Mn from ammonium sulfate, with increasing Mn content in the alloy, the following crystalline structures are observed: beta-Sn, various Mn-Sn intermetallics, and finally gamma-Mn. No solid solutions are observed, only mixtures of these phases. This might have a detrimental effect on corrosion resistance of the coating. Corrosion resistance in chloride environment is good, while in borate environment it depends on the relative amount of the various phases, the Mn-rich phases being dissolved preferentially.

TRANSITION: Transition to this new technology will be facilitated by the use of electrodeposition processes, as the necessary innovation in processing lines would be minimized.

PROJECT SUMMARY

PROJECT TITLE & ID: Clean Dry-Coating Technology for ID Chrome Replacement; PP-1151

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Bruce Sartwell; U.S. Naval Research Laboratory – Washington, DC

FY 2001 FUNDS: $267K

DESCRIPTION: Chrome plating is heavily used throughout the DoD on almost any system subject to wear - aircraft, ships, tanks, guns, hydraulics, etc. It is used by both original equipment manufacturers (OEM) and overhaul and repair (O&R) depots. In order to avoid all the high volume waste streams inherent in wet plating technologies, the research team proposed dry-coating methods - plasma sprayed WC-Co (Tungsten Carbide-Cobolt) for internal diameter (ID) as small as 1.5". Recent work funded by Defense Advanced Research Project Agency (DARPA), Office of Naval Research (ONR), and the commercial sector has shown that plasma spray with small (1-10um) or nanoscale powders (20 um agglomerates or 20nm particles) produces very smooth coatings with the porosity and adhesion of high-velocity oxygen fuel (HVOF). The hypothesis is that small or nano particle spray with existing ID plasma guns will satisfy most of the needs for landing gear (greater than 3" IDs), which is the largest aerospace use of ID chrome. Development of suitable spray method for miniature ID guns will extend the plasma spray process to 1.5" ID to reach most of the actuator components, and modification of these guns may permit us to reach 1" ID for the smallest pins, hydraulic actuators, etc. For some applications, such as sidewalls of grooves in IDs, or very thin-walled, heat-sensitive components, the ESD process is likely to be more cost-effective. ESD is a consumable electrode micro-welding technology with heat input that is extremely small and limited to the surface layer, and it is ideal for small areas and difficult geometries.

The objective of this project is to develop an ID coating technology that is clean, can be used for rebuilds, is environmentally acceptable, and can fit with both the OEM and the depot maintenance production environments. This will be accomplished in four tasks: (1) Conducting research on the deposition of smooth, high quality plasma spray WC-Co coatings on IDs greater than 2.5", using existing guns with small particles and with agglomerated nanoparticles, (2) Developing and testing new miniature ID plasma spray gun for use with small particles and nano-agglomerates which could drive the minimum coatable ID down to 1", and (3) ensuring that the technologies not only provide good performance at an acceptable cost, but also fit the diverse needs of both OEM and depot maintenance operations.

BENEFIT: The immediate environmental benefit of the thermal spray approach is the complete elimination of hexavalent chrome mist and the chrome-contaminated toxic wastes associated with both chrome plating, stripping, and masking operations. The work will lead directly to ID coating methods that are clean and produce a higher quality, longer lasting product. This coating method has the potential for significant cost reduction in both production and sustainment. In general WC-Co coatings last at least 2 - 3 times longer than hard chrome. This leads to lower frequency-of-repair, better mission-readiness, and the ability to keep a lower spare parts inventory. The much reduced production time over chrome plating gives faster turn-around in overhaul operations, also enhancing mission-readiness and reducing inventory requirements.

ACCOMPLISHMENTS: A test-sample jig has been designed and fabricated to carry out coatings on test specimens in an ID geometry at NRC. Initial tests have been run to measure particle temperature and velocity with the Sulzer Metco F100 gun using 3 different-sized WC-Co powders. Initial determinations have been made of the operational ranges of the gun for these powders. Results were essentially as expected. It is possible to accelerate, melt (and even overheat) the powders in a very short distance, meaning that it will be possible to achieve adequate powder temperature within the confines of an ID. Large powder particles were relatively slow and the coating porous. Small powders were faster, but overheated more readily, showing complete carbide degradation and forming an alloy rather than a composite, again as expected. This means that it should be possible to choose the correct conditions for optimal deposition of WC-Co within a bore. Particle temperature will need to be controlled to prevent overheating, while particle velocity will need to be as high as possible for minimum porosity.

TRANSITION: The project is designed to feed directly into an equipment and process development and demonstration/validation program that will be able to follow rapidly upon the completion of the SERDP program. The final deliverable will be a technical report detailing the plasma spray methods that are ready for demonstration and validation.

PROJECT SUMMARY

PROJECT TITLE & ID: Electroformed Nanocrystalline Coatings: An Advanced Alternative to Hard Chrome Electroplating; PP-1152

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Maureen Psaila-Dombrowski; McDermott Technology, Inc. – Alliance, OH

FY 2001 FUNDS: $515K

DESCRIPTION: Hard chromium coatings (0.25 to 10 mil thick) are used extensively for imparting wear and erosion resistance to components in both industrial and military applications. This is because of their intrinsic high hardness (600-1000 VHN) and low friction coefficient (<0.2). The most common means of depositing such hard chromium deposits has been through the use of chromic acid baths. Health risks associated with the use of hexavalent chromium baths have been recognized since the early 1930's, wherein skin irritation and inflammation were identified. More recently, such hexavalent Cr baths have been shown to enhance the risk of cancer of the lung and nose.

Electrodeposited nanoscale coatings of metals and alloys provide the method via grain-refinement (3mm to 100nm avg.grain size) and Hall-Petch strengthening, to produce hard coatings which meet or exceed the hardness and wear performance of current (hard) chromium plating technology. Of particular importance is that these properties are attained using more environmentally benign chemistries (e.g., Fe, Zn, and Co-based systems). The objective of this program is to develop and optimize an advanced nanoscale coating technology based upon modification of environmentally-benign conventional electroplating techniques which will yield coatings that meet or exceed the overall performance and life-cycle cost of existing hard chromium electroplating. The proposed nanoscale coating approach, which is based upon electroplating, would allow for the retention of numerous benefits associated with hard chrome coating technology (i.e., non-line-of-sight application, excellent coating adhesion, dimensional consistency and superior surface finish).

The technical approach will consist of a three-phase program. Phase I provides identification and preliminary experimental assessment of suitable nanoscale electrodeposition systems which satisfy the environmental objective and provide the mechanical performance requirements. This phase will focus upon identifying the most promising systems from an environmental performance and cost perspective. Phase II will deal with developing and optimizing the most promising systems identified in Phase I and will incorporate additional performance evaluation including wear, thermal stability, and corrosion testing. Phase III efforts will be focused upon the optimization of nanoscale 'bore-plating' techniques which represent key applications for the DoD.

BENEFIT: This program will allow the complete elimination of hexavalent chromium at rework, maintenance and manufacturing facilities within the DoD. DoD currently spends over $10 million dollars per year in hazardous material disposal costs associated with hard chrome electroplating. The proposed nanoscale coating approach would allow for the retention of numerous benefits associated with hard chrome plating technology (i.e., non-line-of-sight application, excellent coating adhesion, dimensional consistency and superior surface finish). In addition, this approach will allow for the use of existing hard chrome plating infrastructure within the defense sector. This will significantly reduce the time and cost to practical implementation. Moreover, the proposed nano-technology is expected to provide significant performance and life cycle cost benefits over current hard chrome plating technology.

ACCOMPLISHMENTS: Polycrystalline, nanocrystalline and amorphous cobalt phosphorus (Co-P) electrodeposits have been produced. Nanocrystalline Co-P alloys ranging in composition from 0 to 5% phosphorus have been produced from a stable chloride-based bath chemistry. The as-deposited hardness ranges from 350 to 450 VHN for the polycrystalline samples and 690-800 VHN for the nanocrystalline/amorphous samples. The as-deposited hardness has a strong dependence on the phosphorus content in the deposit, increasing from ~570 VHN for pure nanocrystalline cobalt to over 800 VHN for Co~5wt%P. An additional increase in hardness can be obtained by annealing the as-deposited materials at 400°C for up to 10 minutes. The maximum hardness obtained after annealing a Co-P sample is 1098 VHN. By alloying cobalt with phosphorous the thermal stability is increased by nearly 100°C to over 400°C. The maximum effect of phosphorous addition on thermal stability was achieved with 0.56wt% phosphorous. Little increase in stability is observed with further increases in phosphorus content. The effect of the process variables such as bath chemistry, current density, pulse vs. direct current deposition, temperature and pH have been examined for the electrodeposition of nanocrystalline cobalt phosphorus alloys.

TRANSITION: It is anticipated that the proposed nanoscale coating technology will fully utilize the existing hard chrome plating infrastructure (i.e., contractors, equipment, specifications, etc.) with minimum capital expenditure, thus significantly reducing the time and cost to practical implementation within the DoD. The specific deliverables from this project include an environmentally compatible electrodeposition process to replace hard-chrome electroplating, suitable electrodes and fluid delivery system for a DoD non-line-of-sight application, annual reports, peer reviewed articles and design guidance on further applications.

PROJECT SUMMARY

PROJECT TITLE & ID: Reduced Particulate Matter Emissions for Military Gas Turbine Engines Using Fuel Additives; PP-1179

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mel Roquemore; Air Force Research Laboratory – Wright-Patterson Air Force Base, OH

FY 2001 FUNDS: $728K

DESCRIPTION: It is estimated that U.S. military aircraft emit about 600,000 kg of particulate matter into the atmosphere each year. Most of this particulate matter is in the form of soot particles with diameters less than 2.5 microns (PM2.5). There is a growing body of evidence that these small particles cause both health and environmental problems. The technical objective of the program is to develop one or more fuel additives for JP-8, JP-5, and diesel fuels that will reduce both the mass Emissions Index, EI (M), (grams of PM2.5 emissions/kilogram of fuel) and the number density Emissions Index, EI (ND), (particle number density/ kilogram of fuel) of PM2.5 at the exhaust exit of military gas turbine engines by 70 percent. The additive should be benign to the environment and the fuel system, cost no more than $0.01 per gallon of fuel, and not reduce engine performance and life.

Three complimentary technical approaches will be followed concurrently in developing a PM2.5 additive: (1) a fundamental approach, (2) a Quantitative Structure Activity Relationships (QSAR) approach, and (3) a select and test approach. The fundamental approach is to conduct basic experiments with additives that have shown a tendency to reduce PM2.5 emissions. The experiments are designed to give insight into the additive mechanisms so that improved additive formulations can be developed. The QSAR approach will be used to provide a mathematical formula that correlates PM2.5 reductions to molecular, chemical, and physical properties. The formula will be used to select the next generation of additives to be tested. The select and test approach involves obtaining additives from additive companies and testing them. The companies will be given the results of the additive tests so they can reformulate their additive package and submit it for the next round of testing.

BENEFIT: In the near term, these fundamental additive studies will support the SERDP sponsored NIST research on gaseous emissions and particulate formation for turbine and diesel engines. The insights gained from these studies will be valuable to the understanding of PM formation processes and provide other researchers with a valuable resource for the design of next generation PM mitigating additives. The fundamental experiments involve simple experimental geometries that can be easily modeled; that information will be useful in developing and designing low PM emissions combustors. Finally, an additive or additives will be identified which reduces PM emissions from gas turbine engines by 70%. In the long term, Base Commanders and managers will be able to meet military readiness and local air quality standards of the Clean Air Act Amendments (1990) and upcoming amendments to this Act.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: The project will provide a new methodology for evaluating additives to reduce PM emissions from turbine and diesel engines and provide a fundamental understanding of PM emissions from turbine and diesel engines for military and commercial applications.

PROJECT SUMMARY

PROJECT TITLE & ID: Castable, Solvent-Free Red Phosphorus Smokes for Target Markers; PP-1180

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Daniel Nielson; Thiokol Propulsion – Corinne, UT

FY 2001 FUNDS: $169K

DESCRIPTION: Red Phosphorus (RP) is a material used historically for the production of certain types of target markers. Although mature and reliable, the current process involves the use of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs), which are usually quite flammable, electrostatic discharge (ESD) sensitive, and harmful and/or toxic if inhaled or ingested. The technical objective is to develop castable or pourable, chemically-cured RP formulations with sufficiently high binder content to totally eliminate the need for solvent processing aids, while concurrently mitigating ESD sensitivity. This must be achieved while still maintaining the burn characteristics and white smoke-cloud formation produced by existing RP formulations.

The project will initially evaluate three types of chemically cross-linked energetic binders in RP smoke formulations. Energetic polymers that will be evaluated are poly-azide polymers (e.g., glycidyl azide polymer), nitrate ester polymers (e.g., plasticized nitrocellulose) and inert polyether polymers with energetic plasticizers. The same core set of tests used to establish the rheology/processing characteristics, hazard sensitivity, structural (mechanical) integrity and ignition and combustion characteristics will be used to determine the binder system. The best performing RP smoke formulations will be evaluated as potential prototype target markers.

BENEFIT: There are many benefits of the proposed formulations and processes in comparison to the current ones. Advancements in terms of cost savings, increased safety, and environmental concerns are expected for the solvent process, cast process, solvent waste, and VOC usage. The proposed formulations and processes should also provide extended storage life, required smoke, and higher production efficiency. Castable RP smokes offer very low risk for transitioning to large-scale production. Extensive manufacturing infrastructure and capability exists in the private industry and government facilities to batch-mix and cast solvent-free compositions like those proposed for this program.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: The developed formulation and process will be transitioned to the demonstration and validation phase based on successful test and evaluation of fully configured Army, Navy, and Air Force red phosphorous target marking and obscuring rounds. The proposed technology could be transitioned to any industry with similar facilities, equipment and technical capability.

PROJECT SUMMARY

PROJECT TITLE & ID: Environmentally Compliant Sprayable Low Observable Coatings that Facilitate Rapid Removal and Repair; PP-1181

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Kovar; Foster-Miller, Inc. – Waltham, MA

FY 2001 FUNDS: $578K

DESCRIPTION: Since the enactment of the 1990 Clean Air Act Amendment, the U.S. military and aerospace industry has achieved large reductions in emissions of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) from aircraft coating application and removal processes. NESHAP set limits averaging approximately 400 g/L of VOCs for general aircraft coatings; however, specialty coatings, including radar absorbing material (RAM) coatings for low observable (LO) aircraft were exempt from the 1998 NESHAP implementation. Although many RAM coatings contain a very high level of VOCs (>600 g/L), the EPA agreed to exempt LO coatings due to a lack of suitable low VOC RAM substitutes and due to the comparatively low volume of usage at that time. Over the next decade, the U.S. military plans to deploy several new weapons systems that utilize low observable technology and to retrofit several existing systems to render them more "stealthy." As a result, the emission of VOCs from RAM coatings is expected to increase up to 2 million pounds per year.

This project will develop an innovative No-VOC Low Observable Coatings (NVLOC) system that will meet or exceed all current and projected DoD mission requirements for RAM coatings, and will effectively eliminate the generation of VOCs and HAPs in the initial application. It may be possible in subsequent work to render these No-VOC RAM coatings to be easily stripped / removed and reapplied in an environmentally benign manner. In addition this coating will permit improved, low-cost methods for spot removal and repair of these environmentally compliant LO coatings.

BENEFIT: The immediate environmental benefit will be the elimination of the disproportionate amount of VOCs and HAPs generated by the application of LO coatings. Successful implementation will result in a nearly 100 percent reduction in VOC emissions generated during the spray application of RAM coatings. Potential cost savings related to the elimination of VOCs is estimated to be between $9 to $30 million annually. These No-VOC coatings may also lead to a rapid, effective HAPs-free coating removal process. Radical reductions in labor hours are expected. More environmentally friendly coating removal processes may also be feasible in the future.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: This environmental benign coating technology will provide a tremendous reduction in the life cycle cost as well as improved availability/mission readiness of LO aircraft with potential applications for other weapons systems.

PROJECT SUMMARY

PROJECT TITLE & ID: Ultraviolet Light Surface Treatment as an Environmentally Benign Process for Production, Maintenance, and Repair of Military Composite Structures; PP-1182 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Lawrence Drzal; Michigan State University – East Lansing, MI

FY 2001 FUNDS: $99.5K

DESCRIPTION: Polymer matrix composites (PMCs) are used extensively in many DoD applications. A wide range of both thermoset and thermoplastic matrices reinforced with various fibers and particulates are in use or planned for the future in land, sea and air weapon systems. In the majority of applications, the PMC is fabricated into structure using adhesive bonding technology that has to be maintained and repaired. In addition, paints and specialty coatings have to be applied to PMC surfaces for mission specific applications. Surface preparation of the external polymer surfaces of the PMC is critical to attaining adhesive bonding and paint or coating performance. Manufactured polymer, polymer composite, and metallic surfaces always contain undesirable compounds or additives that reduce the adhesive or paint film. The technical objective of this project is to develop a low-cost, high-speed, environmentally benign dry surface treatment method for the production and repair of military composite structures using ultraviolet (UV) light in ambient air. The technical approach includes the following tasks: (1) investigate the use of UV light treatment in air to clean and modify the surfaces of the typical PMCs used in DoD systems; (2) determine the effectiveness of this surface preparation for the production and/or repair of adhesive-bonded PMC structures; and (3) determine the environmental, cost, and performance benefits of this pulsed UV method as a new, environmentally benign processing method for the production and/or repair of adhesive-bonded and/or coated PMC structures.

BENEFIT: The potential advantage of this method is that it would eliminate volatile organic compounds, reduce or eliminate the use of solutions and detergents, and provide a robust surface that would enhance the wetting and spreading of paints, coatings, and adhesives on polymeric and inorganic surfaces treated by this method.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: A final report will be issued which provides an objective assessment of the viability of using this pulsed UV method as an environmentally benign surface treatment for PMCs. Standard chemical engineering process estimation methods will be used to estimate the potential cost of implementation for DoD applications.

PROJECT SUMMARY

PROJECT TITLE & ID: Investigation of MIC Materials for Electrically Initiated Lead Free Primers; PP-1183 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Ron Jones; Naval Air Warfare Center – China Lake, CA

FY 2001 FUNDS: $100K

DESCRIPTION: Primers containing traditional lead compounds and other toxic materials are a significant source of pollution that can endanger the health of production workers, end users, and others. These lead-containing materials and byproducts represent serious threats that can contaminate the atmosphere, the soil, and groundwater. This project will evaluate the use of a novel lead-free compound in the production of medium caliber electrically initiated primers for aircraft gun ammunitions. The ultimate end product will be an electric primer composition that does not depend on the use of lead as a component and provides equal or better performance than current materials. The approach will include investigating the electrical and thermal properties of the Metastable Intermolecular Composite (MIC) compounds to determine their effects on the performance of lead-free primers. After developing a functional primer mix based on the use of the MIC materials and the fabrication of test articles, NAWCWD Ballistics Test Laboratory will conduct functional tests. The test program will also include the determination of minimum and maximum voltage and current levels to achieve "no-fire" and "all-fire" conditions, under all appropriate conditions. The final step in the validation of the proposed design approach will be to produce a small number of 20 mm rounds and test fire them.

BENEFIT: Significant health and cost savings benefits will be accrued through the elimination of lead in the manufacture of medium caliber ammunition primers. Health benefits will be experienced by those involved in the production of the lead containing energetic materials, those that assemble the primers, by the ultimate users of the ammunition and finally by those that would be involved in the clean-up of contaminated environments. The financial benefits will primarily be seen in the future and will result from the elimination of contamination and the resulting clean-up activities. There may be unknown technical or performance benefits that will not be known or recognized until the program has made measurable technical progress.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: A sufficient number of rounds will be fired to produce a reasonable level of confidence that the interim design resulting from this initial exploratory development effort will produce satisfactory performance of the round and could be transitioned to a final configuration that meets the military Service's needs.

PROJECT SUMMARY

PROJECT TITLE & ID: Electrostatic Fuel Atomization for Gas Turbines to Achieve Reductions in Particulate Emissions; PP-1184

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. David Guimond; Naval Surface Warfare Center – Philadelphia, PA

FY 2001 FUNDS: $460K

DESCRIPTION: A quantum particulate matter (PM) emissions reduction is possible with implementation of electrostatic atomization technology into today's military gas turbine engines. Other benefits include improved fuel consumption at low power, reduced gaseous emissions, reduced carbon fouling, and quantum reduction in fuel pump parasitic loss and cost. Fuel atomization has a first order effect on the formation of PM in virtually all combustion processes. The objective of this project is to develop and evaluate the capability of electrostatic atomization fuel injection technology to achieve reductions in particulate and gaseous emissions produced during the combustion process in Navy gas turbine engines. The current technology consists of a dual orifice nozzle with electrostatic injectors. CFD Research, Allison, and the Naval Surface Warfare Center Carderock Division (NSWCCD) will perform a proof-of-concept test with an Allison 501-K gas turbine engine. Charged Injection Corporation will adapt the recently patented electrostatic atomization breakthroughs to the 501-K fuel injector primary nozzle.

BENEFIT: The goal of the project is to demonstrate an 80% reduction in PM2.5 with electrostatic fuel atomization technology. The baseline emissions of the engine will be compared with the emissions from the same engine after the electrostatic fuel atomization technology has been installed. In addition to emission reduction, the proposed electrostatic atomization fuel injection technology would provide a payback from improved combustion efficiency at part power operation at which ships typically operate. Navy ship propulsion gas turbine engines operate at 33 percent of full load power capacity, on average; similarly, ship service gas turbine engines operate at 50 percent of full load power capacity, on average. During typical part power operation at low to mid-range power levels, combustion efficiency is approximately 93 percent. With the electrically atomized fuel nozzle system, analysis indicates efficiencies of 98 percent. Annual savings per ship would be $120,000 (3 engines x $40,000). Thus the average savings over the fleet of 50 DDG51 ships would be $6,000,000 per year.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: At the conclusion of the project, NSWCCD will coordinate the transition of this technology to a Dem/Val program on a fleet ship service gas turbine generator set.

PROJECT SUMMARY

PROJECT TITLE & ID: A NIST Kinetic Data Base for PAH Reactions and Soot Particle Inception during Combustion; PP-1198

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. George Mulholland; National Institute of Standards & Technology – Gaithersburg, MD

FY 2001 FUNDS: $415K

DESCRIPTION: Polycyclic aromatic hydrocarbons (PAH) are key molecular precursors to soot formation, but there is little known about their rates of formation and evolution in a flame environment or the dynamics and structure of the transition from a large PAH molecule to an incipient soot particle. The overall objective is to develop a NIST chemical kinetic database and an accompanying particle formation model that will describe the transformation of fuel molecules to their desired end products of carbon dioxide and water and the undesired end products of PAH and soot. The specific processes to be considered are fuel breakdown to precursors and subsequent growth to PAH, key gas-phase PAH formation/destruction chemical reactions, and key PAH-to-particle transition steps. The database and model will contain experimental data collected in a shock tube and in a novel well-stirred reactor with flow "chopped" PAH injection. Both atmospheric and high-pressure experiments will be performed. The database will be rigorously evaluated and extended with the recently developed NIST CHEMRATE computer program. The deliverable will consist of chemistry and particle-inception models that can be used in computational fluid dynamic models of diesel and gas turbine engines.

BENEFIT: Manufacturers of military aircraft engines have a strong interest in understanding soot formation in gas turbines. The deliverable will be a publicly available NIST database and soot inception model adaptable for use in computational fluid dynamic (CFD) models of diesel and gas turbine engines.

ACCOMPLISHMENTS: This is a FY 2001 New Start.

TRANSITION: GE has agreed to monitor our progress, provide technical guidance when needed, and ensure that our efforts possess transition potential and remain relevant to the needs of aircraft engine designers.

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APPENDIX E
FY 2002 Statements of Need

The objectives of SERDP are to support environmental research and development projects to meet high priority, DoD mission-related environmental needs. The major annual, or "**Core**," solicitation occurs each year and provides funding in various amounts for multi-year projects. The **SE**RDP **E**xploratory **D**evelopment, or **SEED**, solicitation also occurs annually and is a means for researchers to test proof-of-principles concepts during an effort of one year or less. The SEED program is designed to provide support for high-risk, high-payoff projects in which funding is limited to a maximum of $100,000 for one year. This appendix contains brief summaries of all SERDP FY 2002 Statements of Need (SON). Complete SONs can be viewed on the SERDP website, www.serdp.org, under the Funding & Opportunities option.

CLEANUP

Core Statements of Need: **Page**

SEED Statements of Need:

COMPLIANCE

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SERDP CORE STATEMENT OF NEED FOR FY 2002
CLEANUP – CUSON-02-01

IMPROVED UNDERSTANDING OF IN SITU CHEMICAL OXIDATION (ISCO)

OBJECTIVE: This statement of need (SON) seeks fundamental or applied studies to improve our understanding of: (1) the mode of action of oxidants on free phase and residual dense nonaqueous phase liquids (DNAPLs), including the associated chemical reactions, reaction kinetics, and other effects that can impact overall destruction efficiency; (2) the stability and reactivity of oxidants in an aquifer matrix with varying soil conditions (pH, iron content, etc.); and (3) the impact of varying soil parameters on oxidant fate and overall destruction efficiency. Results from these efforts should lead to: (1) an improved understanding of the potential of in situ chemical oxidation for the destruction of DNAPLs; (2) identification of the limitations associated with ISCO; and (3) development of improved application methodologies.

Results of this research should directly support the DoD's goal to develop guidance for the use of ISCO. Guidance is needed on selecting ISCO technology for specific site conditions, selecting among the different technical approaches that are available, and incorporating ISCO into an overall site cleanup strategy. Modeling efforts will be considered only to the extent they build on experimental data developed during the research.

BACKGROUND: There are nearly 17,000 sites on DoD installations potentially requiring environmental cleanup. The challenges facing those responsible for cleanup include selection of appropriate remedial actions that will treat the contaminated soil and groundwater to established cleanup standards. Recently, there has been increasing interest in the use of technologies to remove/destroy source zones in situ. Remedial project managers are often faced with determining whether such technologies are appropriate for their site, and there is little guidance on the selection and design of ISCO systems.

ISCO is increasingly being tested and implemented at DoD sites because it is considered a rapid and relatively inexpensive method to destroy contaminants such as chlorinated solvents in situ. There are several commercial approaches to implementing ISCO, using different oxidants, concentrations, and environmental conditions (e.g., preacidification). However, as compared to other techniques such in situ biological or thermal treatment, there has been little fundamental research on ISCO that could serve as the basis for guidance on the use of the technology. Significant questions remain regarding the mode of action of chemical oxidants, the impacts of site conditions on efficacy, the nature and fate of potential byproducts, and any potential secondary impacts (e.g., metal dissolution, volatile emissions, aquifer plugging). In situ reaction rates, and the environmental factors controlling the reaction rates, are also not well understood.

In addition, there have been several reports of unexpected problems during well-designed applications (e.g., contaminant migration to new areas, surface cracking, steam emissions, and increased metal concentrations), as well as accidents such as fires, wellhead blowouts, and explosions. Preventing such problems requires formalized monitoring and operational guidelines currently not available, and is dependent on a better fundamental understanding of oxidant behavior in the subsurface.

SERDP CORE STATEMENT OF NEED FOR FY 2002
CLEANUP – CUSON-02-02

IMPACTS OF SOURCE ZONE TREATMENT

OBJECTIVE: The purpose of this statement of need (SON) is to develop an increased understanding and characterization tools to better assess the need for and impacts of source zone treatment technologies. Specifically, this SON seeks fundamental or applied studies that will result in or lead to assessment tools or approaches to evaluate the site specific appropriateness of dense nonaqueous phase liquid (DNAPL) source zone removal/destruction technologies and/or an ability to predict the effect of source zone removal/destruction on the dissolved phase plume. This SON seeks an improved understanding of the costs and benefits of technologies designed to remove or destroy residual sources of chlorinated solvents in the subsurface.

The focus of this SON is not on specific innovative technologies for source removal, but rather on the development of a fundamental understanding of the long-term impact of source zone removal technologies to allow rational selection, design and assessment of such technologies.

BACKGROUND: There are nearly 17,000 sites on DoD installations potentially requiring environmental cleanup. Developing cost-effective remedial strategies for these sites remains a significant challenge. The most common contaminants at DoD sites are chlorinated solvents, and many sites have subsurface sources of solvents, as dense nonaqueous phase liquids (DNAPLs), that serve as long-term sources of dissolved-phase contamination. Because complete cleanup of these sites has generally been considered technically impracticable, the typical response has been containment by pump-and-treat systems, reactive barriers, or by monitored natural attenuation where appropriate.

Containment systems may operate for decades at sites with residual DNAPL sources, because the DNAPL sources are depleted very slowly. As a result, the operations and maintenance of engineered containment systems has become a large proportion of DoD environmental budgets, and these costs may continue long into the future. Technologies designed to remove subsurface sources of contaminants, particularly DNAPLs, have received tremendous recent interest. Several approaches have been developed and tested, including thermal treatment technologies, chemical oxidation, bioremediation, and enhanced physical removal (using cosolvents or surfactants, for example). Under appropriate conditions, these technologies can remove a large fraction of the total mass. Such treatment could reduce the need for engineered containment systems, or the duration of the O&M for such systems, if natural attenuation can be effective in containing any residual source remaining after treatment.

However, there is controversy regarding the benefits of using such technologies. Key questions for site managers include: (1) Are the costs for source removal technologies justified, in terms of reduced need for or duration of active containment; (2) How much source removal is required to cease active containment at a given site; (3) How much contaminant migration outside the treatment zone can occur; and (4) How much of the original source can remain after removal technologies are used, and still ensure protection of human health and the environment under different site conditions? These questions cannot be answered without being able to predict the future plume dimensions and concentrations once a new equilibrium is established, as well as the effects of source treatment on the timing and extent of future plume contraction.

SERDP CORE STATEMENT OF NEED FOR FY 2002
CLEANUP – UXSON-02-01

UNEXPLODED ORDNANCE (UXO) SITE CHARACTERIZATION AND REMEDIATION ALTERNATIVES FOR HIGHLY CONTAMINATED SITES

OBJECTIVE: The objective of this statement of need is to develop technologies to support clearance actions for unexploded ordnance found on highly contaminated sites. Research and development proposals should focus on one or more of the following activities.

- Improved signal processing and or sensors to aid in discrimination clutter from targets in contaminated areas where overlapping signatures are common.

- Mechanical or other methods to aid in the cost effective and safe direct clearance of highly contaminated sites.

- Analytic work and supporting technologies to aid in the decision process for determining the appropriate clearance action or combination of clearance options.

Modern geophysical surveying techniques can be effectively be used to characterize sites potentially contaminated with unexploded ordnance (UXO). For sites where signatures are sparse and anomalies are spatially isolated, these tools can guide detection-driven remediation activities and in some cases can effectively screen clutter from ordnance. However, many sites contain highly contaminated areas such as target bull's-eyes, where geophysical signatures from sub-surface anomalies overlap. In these cases, methods of discrimination have not been adequately developed and demonstrated. In fact, it is possible that in some highly contaminated cases the most appropriate course of action may be mechanical treatment (or other direct clearance approaches) of portions of the earth, such as sifting or plowing, rather than detection-driven excavation of individual targets or some appropriate combination of both. The appropriate clearance approaches will depend on the ordnance type and fill, geological conditions, extent of clutter and other factors.

BACKGROUND: As a result of past military training and weapons testing activities, UXO is present at sites designated for base realignment and closure (BRAC) and at Formerly Used Defense Sites (FUDS). In many cases, the actual contamination is highly concentrated on subsections of the potentially contaminated land, such as target areas. To appropriately direct remediation efforts and to reliably clean these areas, it is desirable to develop techniques that provide reliable target detection and discrimination, remediation tools that can cost effectively and safely remove UXO and associated metallic clutter, as well as prescribe what combination of detection–driven approaches and mechanical or other removal actions should be used.

SERDP CORE STATEMENT OF NEED FOR FY 2002
CLEANUP – UXSON-02-02

UNEXPLODED ORDNANCE (UXO) SITE CHARACTERIZATION FOR LARGE AREAS OF ROUGH OR VEGETATED TERRAIN

OBJECTIVE: The objective of this statement of need is to develop sensors, processing approaches and/or innovative platforms, which will provide a new capability to cost effectively characterize large sites (1000s of acres) suspected to be contaminated with unexploded ordnance (UXO). The approaches proposed must be applicable to rough and/or vegetated terrain. Standoff systems are required that would allow detection of ordnance and ordnance like objects reliably enough to distinguish contaminated from uncontaminated regions. The footprint required for detailed geophysical surveys can be reduced if the processed information from standoff systems can distinguish, with high confidence, approximate boundaries of contamination within larger sites. It is also desired to develop standoff systems that would provide sufficient information to allow for remediation decisions regarding individual detected geophysical anomalies. Current airborne technologies (helicopter based magnetometry) that provide the capability to characterize open flat terrain where sensors may be flown at very low altitudes (2 meters) have been developed and are currently being demonstrated. The objective of this statement of need is to develop systems with significantly enhanced capabilities over these existing systems.

BACKGROUND: As a result of past military training and weapons testing activities, UXO is present at sites designated for base realignment and closure (BRAC) and at Formerly Used Defense Sites (FUDS). Current estimates indicate that many million acres of land potentially contain UXO. Many of these sites are 10,000 acres or larger. However, in many cases, the actual contamination is concentrated on subsections of the potentially contaminated land, such as targeting areas or in isolated burial pits. Historical records are often limited and insufficient to differentiate between which lands require detailed ground based surveys and which lands may be fully released for other uses. To appropriately direct detailed geophysical surveys, it is desirable to develop sensor and processing systems, which can identify regions of likely contamination, and exclude other regions. In addition, rough terrain and heavy vegetation can make even ground-based surveys difficult, time consuming and costly.

SERDP SEED STATEMENT OF NEED FOR FY 2002
CLEANUP – SEEDSON-02-02

ALTERNATIVES TO MICROBIAL MICROCOSM STUDIES

OBJECTIVE: The objective of this statement of need is to develop alternatives to the current practice of utilizing microbial microcosm studies to support the selection, design, operation and monitoring of bioremediation strategies. Successful application of bioremediation on a site-specific basis requires extensive and intense scientific and engineering analysis. Often, microcosm studies are the "tool of choice" for making these assessments and developing appropriate engineering design criteria describing the anticipant microbial response to site-specific geochemical conditions. Less costly and more rapid advanced test and evaluation techniques are needed to assist in the evaluation and design of site-specific bioremediation strategies.

Rapid methods of predicting potential degradation activity and/or in situ kinetics of biodegradation without using microcosms are being sought. Validation of any new method against conventional methods or with in situ rate kinetics will be a critical step in any follow-on work.

The proposed work should explore the proof-of-concept for test and evaluation technologies that will minimize the time required to make engineering judgments related to the probability of successful implementation of bioremediation on a site specific basis. Projects should plan to include simple cost assessments for operational concepts to justify future development efforts. The proposed work could, if successful, lead to a continued development effort.

BACKGROUND: Variants of bioremediation have become accepted practice for most classes of organic contaminants. Microcosm studies are a common technique used to evaluate the efficacy of bioremediation on a site-specific basis. Microcosm studies are time consuming, costly, and require substantial technical resources. The cost associated with evaluating the efficacy of bioremediation for site-specific application represents a substantial cost in time and funding. Microcosm studies have become an integral part of the evaluation process, contributing to the increased time and costs of remedy selection. As bioremediation gains acceptance for an increasing variety of contaminants, microcosm studies represent a significant portion of the site remediation cost to the DoD.

SERDP is interested in developing technologies that can reduce the time required and total cost (both dollars and personnel resources) of evaluating bioremediation as an appropriate site specific technology and ultimately, developing the engineering parameters that can be used for process design, operation, and maintenance. Specifically, SERDP is interested in technologies that can be used as a substitute for/or augmentation of microcosm studies. The primary contaminants of concern include volatile organic chemicals (especially chlorinated solvents), explosives and propellants, and petroleum related compounds.

SERDP SEED STATEMENT OF NEED FOR FY 2002
CLEANUP– SEEDSON-02-03

ALTERNATIVE TECHNOLOGIES FOR LONG TERM MONITORING

OBJECTIVE: This statement of need (SON) seeks improved engineering hardware/systems for cost-effective monitoring of contaminants in groundwater and/or soil. The purpose of this statement of need (SON) is to solicit proposals to develop technologies that can be implemented to reduce the financial, personnel, and technical resources necessary for long term monitoring of sites undergoing restoration. Potential applications of the technology include: groundwater and soil assessments.

The proposed work should focus on proof-of-concept for developing innovative engineered hardware/systems for quantifying chemical contaminants in complex environmental settings. Groundwater is the primary environmental media of concern, however, hardware/systems for monitoring soil will also be considered. Primary contaminants of concern include DoD relevant explosive and propellant compounds, heavy metals and chlorinated solvents. In situ/on-site measurements are the goal, but interim technologies that are demonstrably able to meet the objective of reduced resource commitment for long term monitoring may be considered. The ideal candidate technology would have the following attributes: (1) on-site, (2) in-situ, (3) low initial investment, (4) extended service life, (5) demonstrable potential to meet regulatory requirements and obtain regulatory approval. Successful proposals shall include a short description of how the technology would be deployed in a field setting and a short evaluation of the projected life cycle cost of the proposed technology.

BACKGROUND: Statement of Problem: There are nearly 17,000 sites on DoD installations potentially requiring environmental cleanup. Many of these sites will require long term monitoring to ensure the protection of public health and the environment. The cost of long-term monitoring of contaminated sites is a significant and growing portion of the DoD cleanup program budget. The costs of long-term monitoring are increasing as more and more sites enter the active remediation and post-remediation stage. Active remediation systems such as "pump and treat" of groundwater and passive remediation systems such as natural attenuation as well as RCRA closure sites often require elaborate and expensive monitoring. This long-term monitoring can be for process control, for performance measurement, or for compliance purposes and can last up to 30 years. Labor costs are a significant portion of long term monitoring costs. Long-term monitoring involves a large amount of time to collect, package, ship, and analyze samples. Waste generated by sample collection must be disposed of and chemical laboratory results can often take up to 3 months to receive in usable form. Improvements in monitoring strategies to reduce the number and frequency of wells sampled and sampling techniques to improve current field sample collection have been developed and are beginning to be exploited. New technologies to further reduce costs are required.

Development of improved technologies for long term monitoring will reduce the life cycle cost of environmental cleanup and facilitate the establishment of more cost-effective and efficient remediation technologies that are protective of human health and the environment. Improved monitoring hardware/systems that will be developed through this SON will enhance the DoD ability to meet regulatory requirements at reduced cost.

SERDP SEED STATEMENT OF NEED FOR FY 2002
CLEANUP (UXO) – SEEDSON-02-04

INNOVATIVE APPROACHES TO UNEXPLODED ORDNANCE (UXO) CLEANUP

OBJECTIVE: The objective of the proposed work is to develop proof of principle for new sensors, explore new discrimination techniques, or illustrate new render- safe or removal technologies, or technologies that support such efforts through improvements in navigation, geo-location or ground or airborne vehicle technologies. Advances are needed in all aspects of the procedures for the detection, discrimination and rendering safe of UXO. Items ranging from 20-mm shells to 2000-lb bombs must be detected and discriminated from other non-hazardous items in the subsurface. Algorithms are needed that can exploit data from current state of the art sensors and advanced sensors that are now becoming available. This must be done in a variety of environments, using a variety of supporting vehicle and navigation technologies. Once hazardous and non-hazardous items are distinguished, the hazardous items must be rendered safe in a cost-effective manner. The proposed work should, if successful, lead to a continued development effort, which ultimately could result in the fielding of new sensors, implementation of algorithms, testing of render-safe procedures, or in the improved operation of the approaches used to date though improved navigation, geo-location or vehicle performance. There is interest in any plausible aspects of improving UXO clean-up procedures.

BACKGROUND: As a result of past military training and weapons testing activities, UXO is present at sites designated for base realignment and closure (BRAC) and a formerly used defense sites (FUDS). Using current technologies, the cost of identifying and disposing of UXO in the United States is estimated to be in the billions of dollars. Current technology has shown the ability to detect individual sub-surface UXO, but not to reliably discriminate UXO from other items that pose no risk. Thus, typical survey methods currently employed require an exhaustive search of contaminated areas, have an excessive level of false alarms, and lead to expensive render-safe procedures with adverse environmental impacts.

SERDP CORE STATEMENT OF NEED FOR FY 2002
COMPLIANCE – CPSON-02-01

SOURCE AND AMBIENT AIR TOXIC MONITORING FOR DOD OPERATIONS

OBJECTIVE: The objective of this statement of need is to identify and characterize emissions of trace air toxic compounds, especially persistent organic pollutants, from operations/activities at Department of Defense (DoD) facilities. The sources and modes of operations that lead to such air toxics via sensitive instruments should also be identified and characterized. Measurements should be made in as near real time as possible and at a high temporal rate. Emissions factors should be developed for those compounds that are characterized.

The chemical compounds for which emissions factors need to be developed include those urban air toxic (UAT) compounds and mobile source air toxics (MSAT) that are emitted by DoD activities/operations. An emission factor is defined by EPA as a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. They are expressed as a mass of pollutant per a unit volume, distance, or duration of an activity emitting the pollutant. Emission factors developed under this SON should be statistically representative of the activities of concern with quantifiable estimates of their uncertainty. DoD activities to be considered under this SON are air emissions from ground vehicles (on-road and off-road), aircraft, marine engines, and stationary engines (e.g., generators).

BACKGROUND: Federal programs to address air toxics nationwide include the Integrated Urban Air Toxics Strategy (UATS), the Mobile Source Toxics Program, the National Air Toxics Assessment (NATA), and the Maximum Achievable Technology Control (MACT) residual risk program. In part, these programs will conduct a national assessment of air toxics, which may lead to mandates for individual source controls or overall air shed requirements for ambient air limits for air toxics. Accompanying the mobile source related sections of the Clean Air Act (CAA) are those sections that more generally focus on toxic release (TRI) emission inventories. Military installations are also required to adhere to Executive Order 12856, Emergency Planning and Community Right-To-Know (EPCRA) in which section 313 reporting requirements for TRI chemicals are accompanied by a goal to reduce releases and toxic chemical transfers 50 percent.

Under the CAA Amendments of 1990, EPA is required to regulate emissions of 188 listed air toxics. EPA is currently conducting a National-Scale Air Toxics Assessment that, when complete, will include 33 air toxics that present the greatest threat to public health in the largest number of urban areas. Under the national Urban Air Toxics Strategy program (the Strategy) put forth by EPA (U.S. EPA, 1999), Section 112(k) of the CAA requires EPA to develop a strategy to identify and address risks to the public in urban areas via development of national standards for stationary and mobile sources to improve air quality. The CAA requires EPA to assure that sources accounting for 90 percent of the emissions of area source hazardous air pollutants (HAP) are subject to standards. The Strategy complements existing efforts by focusing on achieving further reductions in air toxic emissions. The Strategy outlines actions to reduce emissions of air toxins and specifies assessment activities to improve understanding of health and environmental risks posed by air toxins in urban areas.

SERDP CORE STATEMENT OF NEED FOR FY 2002
COMPLIANCE – CPSON-02-02

CHARACTERIZATION OF AQUATIC NON-INDIGENOUS SPECIES FOR DEPARTMENT OF DEFENSE VESSELS

OBJECTIVE: The objective of this statement of need is to develop a better understanding of the role DoD operations play in the introduction of non-indigenous aquatic species that can be used as a guide to the development of new technologies aimed at controlling these introductions. Proposals are being solicited to:

- Quantify the abundance and diversity of organisms in the ballast water of DoD vessels;
- Quantify the abundance and diversity of organisms occurring as hull fouling on DoD vessels;
- Survey a variety of vessels operating on both coasts and on inland waterways; and
- Relate findings as to organism abundance and diversity to operational histories, maintenance histories, and any management practices carried out by crews, that may affect the occurrence of non-indigenous species in or on a vessel.

DoD vessels require unrestricted access to national and international waters to facilitate domestic commerce, and protect and project national interests. Current and developing regulations addressing activities leading to the introduction of harmful aquatic species have the potential to restrict the operations of DoD vessels. Development of treatment technologies designed to control transport of non-indigenous species and be appropriate for use on DoD vessels, will be facilitated by improving our understanding of the extent to which DoD activities lead to the transfer of such species, and the mechanisms by which transfer occurs. The knowledge gained through this effort will support DoD programs by providing the baseline information necessary to determine if and how discharges liable to include non-indigenous species should be treated.

BACKGROUND: Invasions of non-indigenous species continue to present a threat to marine and aquatic environments worldwide. Species introductions can adversely affect regional biodiversity, public health, energy and food supplies, and local economies. Regulatory pressure to control these invasions is increasing at the state, federal, and international levels. The Uniform National Discharge Standards (UNDS) process has identified non-indigenous species as a potential constituent of concern for discharges from Department of Defense (DoD) vessels. Aquatic invasive species can be transported in ballast water and as hull fouling.

Both inter- and intra-continental voyages can result in the inadvertent transfer of non-indigenous species. Ships that never operate outside the continental U.S. may still transport invasive species between affected and unaffected locations within the country. Thus, regulations aimed at controlling invasions may affect not only DoD vessels arriving from overseas, but also vessels participating solely in coastal or riverine operations, or in maintaining domestic shipping lanes.

The UNDS process has identified three discharges from DoD vessels that have the potential to transfer non-indigenous species, including clean ballast and discharges from underwater ship husbandry (with non-indigenous species occurring as hull fouling). The relative importance of these discharges as vectors for the transfer of invasive species is unknown.

SERDP CORE STATEMENT OF NEED FOR FY 2002
COMPLIANCE – CPSON-02-03

OBSERVING AND PREDICTING THE EMISSION RATES, TRANSPORT, TRANSFORMATION, AND FATE OF AIR POLLUTANTS ASSOCIATED WITH DOD ACTIVITIES WORLDWIDE

OBJECTIVE: The objective of this statement of need is to provide an improved observational and predictive ability for the impact of air pollutants emitted as a result of military facilities and operations on local and regional air quality by exploiting existing techniques and observing systems and adapting existing atmospheric chemistry and meteorological models. This objective is motivated by the fact that many DoD facilities are located in, and operations are conducted in, environments such as complex coastal zones where atmospheric, oceanic, and hydrological processes dominate the transport, transformation, and dilution of pollutants. Similarly, other relevant environments range from humid, forested landscapes to high, arid mountainous domains. In addition, DoD operations span the range of ordinary emissions such as from vehicles, aviation, and marine operations to unique operational emissions. The environment into which these emissions emerge also varies on the time scales of hours to seasons to years, all of which need to be accommodated in an observation and prediction system that in turn depends on an optimal mix of observations.

BACKGROUND: Models, together with observations, play a vital role in the study of physical systems responsible for the emission, transport, transformation and dilution of pollutants. However, models depend on (1) accurate emission estimates, (2) the ability to describe the effect of unresolvable processes through simplified mathematical expressions, and (3) observations to guide the model back to reality when it diverges. The optimal mix of observations required for assimilation into models, particularly for complex regions, is still an open research issue. In addition, many processes, such as mixing and turbulence in the nighttime atmosphere, the coupling of the atmosphere to the ocean circulation in coastal areas, the prediction of hydrological cycles on very local scales, and the interaction of chemistry and meteorology on the smallest scales, will require a focused effort to improve our prediction systems.

Special emphasis should be placed on three areas that are currently poorly understood: aviation operations, ship operations, and coastal operations. Recently, new modeling methods and observing techniques have emerged that give promise for advances in these areas. Fully coupled, two-way interacting, ocean-atmosphere-wave models have been demonstrated in the coastal environment. New acoustic, optical, and radar methods are available to probe the atmosphere and offshore buoys now show the promise of supporting combined subsurface, interfacial, and atmospheric profiling measurements in the coastal ocean. In addition, aircraft and UAV-deployable remote sensing will soon be available to further probe the ocean surface and land-surface processes in the near shore area. Further, fully-instrumented aircraft are capable of measuring emission factors for aircraft and ships and tracking the chemical transformation that occur in the pollutants after emission. Lastly, new air quality chemical and meteorological monitoring methods allow baseline measurements to start at DoD installations to allow a more unequivocal observation and attribution of future changes. Together, these advances portend a new opportunity for rapid advances in observing the ocean, land, and atmospheric basic states and numerically predicting the subsequent transport and fate of pollutants.

SERDP CORE STATEMENT OF NEED FOR FY 2002
CONSERVATION – CSSON-02-01

CULTURAL RESOURCES MANAGEMENT DETECTION AND EVALUATION TECHNOLOGIES

OBJECTIVE: The objective of this statement of need (SON) is to develop improved technologies to assist in locating and identifying prehistoric and historic archeological sites on Department of Defense (DoD) and Department of Energy (DOE) lands. There is a need to develop and integrate advanced and emerging technologies to more efficiently and cost-effectively manage these types of cultural resources. Proposals to this SON should address the following:

Provide the ability to effectively detect, locate and identify historic and pre-historic archeological resources on military and DOE lands and ranges. Potential techniques include both improved models for predicting the location of resources and improved technologies for detecting surface and/or subsurface resources. Non-invasive processes/procedures are strongly encouraged in order to reduce the possible disturbance of human remains and associated artifacts. Ground-truth testing is necessary to demonstrate the feasibility of the proposed technologies and associated procedures.

BACKGROUND: A suite of integrated, cutting-edge methods and techniques that improve on traditional cultural resources survey and assessment methods are required to improve both the management efficiency and cost of cultural resource management practices on DoD and DOE lands. Millions of acres of DoD and DOE lands have not been surveyed and thousands of potential sites have not been assessed. However, conventional survey and significance, and mitigation techniques to comply with legal requirements involve time consuming, labor intensive, and unnecessarily destructive excavation. Given current budget climates, traditional conventional means to identify and assess cultural resources are potentially cost prohibitive. In addition, new and unresolved challenges exist for the assessment, evaluation and treatment of traditional cultural properties and human interments (burials). Enhanced technologies are required to meet cultural resource challenges now and in the future. Effective techniques, incorporating geomorphologic information to predict the probability of sites are needed. Evaluation and development of new procedures, such as geophysical prospecting, which may provide dramatic improvements in assessing and evaluating cultural resources and minimizing excavation are needed.

All Federal lands are required to be surveyed, and all archeological sites assessed for eligibility for the National Register of Historic Places (NRHP). Improved techniques for predictive archeological modeling and inventory study design using remote sensing tools and GIS techniques are needed to reduce the cost of survey. Typical costs of existing, time-consuming excavation to assess known sites can cost a minimum of $15K per site. Extant and experimental geophysical techniques (e.g., ground penetrating radar, magnetometry, resistivity, electromagnetics, seismic, graviometry, etc.) offer the potential for more reliable and lower cost NRHP assessments. Owing to the wide range of site variability (e.g., soil types, stratigraphy, moisture content, compaction, natural inclusions), reliable site assessment will often require the use of multiple techniques.

Without reliable, cost effective methods to assess sites, there is continual risk of cost delays in training, testing, and construction due to legal requirements that consider all unassessed sites eligible for listing and protection. In addition, without better technologies to predict undiscovered site locations, the military cannot reduce the risk of inadvertent discovery of significant sites and/or protected human remains.

SERDP CORE STATEMENT OF NEED FOR FY 2002
CONSERVATION – CSSON-02-02

IMPACT OF FOG OIL SMOKE ON INSECT POPULATIONS WHICH MAY BE THE FOOD SOURCE FOR THREATENED AND ENDANGERED SPECIES

OBJECTIVE: The objective of this statement of need is to develop and apply a methodology that will allow the quantification of population dynamics, principally decreased, among the insect fauna in areas subjected to "fog oil" smoke generation during military training. Proposals responding to this SON should meet the following criteria:

- A process or approach shall be developed and applied to at least one realistic environmental setting applicable to DoD insectivorous threatened and endangered species (TES). An approach may be the development of droplet size and quantity versus insect population dynamics.
- The process or approach should result in reproducible measures of "normal" or "undisturbed" conditions or activities against which results obtained in proximity to selected military training and testing actions may be compared.
- The technique/technology must be transferable to other environmental settings.
- The results must be acceptable to the U.S. Fish and Wildlife Service.

The results of this study will help to provide a basis for future biological assessments (BAs), biological opinions (BOs) and endangered species management plans (ESMPs).

BACKGROUND: Given that the DoD must comply with the Endangered Species Act, one of the postulated adverse effects related to military training and testing results from the use of fog oil "smoke" generated for the purpose of battlefield obscuration. The Army has examined acute effects of this smoke on several avian species, and no measurable effects were found. The issue of the potential effects on the insect prey (food source) of insectivorous TES, such as certain birds and bats, has been raised as a possible indirect effect that requires some examination.

The use of the term "smoke" in this context is related to common language usage, and is incorrect insofar as the word is related to a combustion product. Fog-oil is a highly refined hydrocarbon, i.e., a light oil, and the "smoke" is generated by spraying the oil onto a heated metal manifold, where a true fog of minute oil droplets is created, and expelled from the generator. These droplets are carried downwind for up to several kilometers, although concentrations decrease rapidly beyond 100 meters from the generator. The droplet size distribution for smoke generators has been characterized. The downwind movement versus droplet size distribution would assist in determining the possible exposure of beneficial insects to the "smoke."

Speculation about possible effects on insects has focused on several different scenarios. Impurities present in the oil itself may have insecticidal effects, although their concentrations are extremely low. Deposited hydrocarbons themselves may have some effect on the oxygen exchange capability of very small insects and mites, similar to the application of horticultural oil and urban insect control sprays, although the latter two are applied at concentrations at least 100 times that of the military fog oil plumes.

SERDP CORE STATEMENT OF NEED FOR FY 2002
CONSERVATION – CSSON-02-03

IDENTIFYING, CHARACTERIZING, AND PREDICTING IMPACTS OF REGIONAL LAND-USE CHANGE ON THE SUSTAINABILITY OF MILITARY INSTALLATIONS

OBJECTIVE: The overall purpose of this statement of need (SON) is to increase the understanding of the risks to military operations and training associated with land use change outside of military installation boundaries. More specifically the purposes are to identify and examine those land use, compliance, and ecosystem variables, resulting from outside land use change, that represent potential future constraints to the Department of Defense's (DoD) operational mission(s); and develop the analytical tools or approaches to predict changes in these variables as they represent conflicts to the sustainability of military operations. Research should enhance the ability of military installations to understand the implications of external land use change, resource use, and future development policy and how that might impact the sustainability of their lands, ranges, and missions.

Research fulfilling the objectives of this SON will increase the understanding of vulnerabilities associated with regional land-use changes on (1) the ability of military installations to sustain realistic training, weapons testing, and other mission activities; particularly on installations with increasingly encroachment changes in adjacent land areas; and (2) on environmental and ecological resources of installations and surrounding lands and communities. Research will also provide land managers and other decision-makers with tools to evaluate or predict environmental impacts and assess risks under alternative land-use change scenarios. Such information will support more technically sound land management decisions and policies. In addition, these tools will inform a more sustainable coexistence between military installations and adjacent communities, supporting partnerships to achieve mutually beneficial outcomes. An important benefit of this research will be an "early warning" capability to help installations and the military services identify potential mission constraints while there is still sufficient time to develop mitigation strategies that prevent mission impacts.

BACKGROUND: The U.S. Department of Defense maintains over 10 million hectares of land to house and train troops, test weapons, and conduct realistic readiness exercises. The continued availability of these lands, and related sea and airspace resources, is critical for maintenance of readiness and power projection capability. The rapid pace of land-use changes, such as urbanization, occurring all across the U.S. threatens this availability. Complicating the situation further is the fact that while military requirements impacting sustainable land-use are increasing for many installations, the overall availability of training space has decreased as many units have returned from overseas and dozens of installations in the U.S. have been closed or realigned. Because no new lands will likely become available to DoD in the foreseeable future, loss of critical training and testing land, sea, and airspace resources could permanently hinder the ability to conduct some exercises under realistic conditions.

From a military perspective, the importance of understanding land-use change is becoming paramount. Extreme urban growth and the resultant patterns of development are undermining installations' ability to maintain mission capabilities.

SERDP CORE STATEMENT OF NEED FOR FY 2002
CONSERVATION – CSSON-02-04

LOW FREQUENCY (LESS THAN 100HZ) AUDIOGRAM TECHNOLOGIES FOR PREDICTING THE IMPACT OF MILITARY NOISE ON THREATENED AND ENDANGERED SPECIES

OBJECTIVE: The objective of this statement of need is to develop technologies which will allow on to establish the lower frequency end of the range of hearing of a wide variety of threatened and endangered species (TES) and perform limited proof of principal experiments on representative species. Frequencies of concern are associated with military training, in particular impulse noise. Proposals responding to this SON should meet the following criteria:

- Resulting species specific audiograms must display the aural response of the subject species to frequencies of interest to the military-related noise areas of the TES program, defined here as those less than 100 Hz .
- Technology must be applicable to a substantial set of the DoD TES species of interest and/or acceptable surrogates for them.
- The technique/technology must be capable of reliable application by researchers familiar with present audiogram practices.
- The results must be acceptably accurate to the U.S. Fish and Wildlife Service.

It is not anticipated that the effort proposed under this SON will result in the completion of all studies required to obtain the actual species-specific data for each species of concern. It is anticipated, however, that a technology or process capable of acquiring these data will be developed and that it will be tested on a variety of species. The results of these studies will help to provide a basis for future biological assessments (BAs), biological opinions (BOs) and endangered species management plans (ESMPs). The concern here, and the need to provide quantifiable measures, results from the responsibility of the DoD to properly assess the effects of their activities on these listed species.

BACKGROUND: Given that the DoD must comply with the Endangered Species Act, one of the major potential adverse effects relating to military training and testing results from the noise generated by heavy weapons, rotary-wing and fixed-wing aircraft, demolition activities, and other generators of high energy, low frequency sound. The characteristics of this sound are well known, but replicable, species-specific studies which relate animal behavior to generation of these noises are infrequent. There are several reasons for this information gap.

A basic principle of animal behavior is that a species cannot display a response to a stimulus that it cannot perceive. For example, humans show no response to sound at frequencies above 30 kHz, while dogs are sensitive to them. With cooperative, trained subjects, audiograms may be prepared showing the range of frequencies to which the species is sensitive. This has been done for many species, almost all of them common domestic and laboratory animals. Other techniques are used to measure the hearing range. Anaesthetized specimens may be subjected to a range of sounds and electrical activity in the auditory nerve measured following surgery to expose the nerve. Another method (evoked potential) allows measurement of the electrical potential in a non-invasive manner through external electrodes. This is potentially a rapid and non-invasive means of determining sensitivity to these low frequency sounds.

SERDP SEED STATEMENT OF NEED FOR FY 2002
CONSERVATION – SEEDSON-02-01

DEVELOPMENT OF MINIATURIZED SENSORS TO MONITOR OR DETERMINE ECOSYSTEM PARAMETERS

OBJECTIVE: The objective of this statement of need is to develop miniature sensors for monitoring one or more of the following environmental parameters:

- Water quality parameters (dissolved O2, turbidity, etc)
- Waterborne pollutants (metals, PAHs, PCBs, etc)
- Primary production
- Air Quality Parameters (NOx, SOx, ozone, particulates, etc)
- Terrestrial parameters (soil moisture, overland flow, vegetative cover)
- Other indicators of ecosystem health

The preceding list of parameters is meant to be illustrative and is not all-inclusive. Efforts to develop sensors to measure other ecosystem parameters are encouraged. It is desirable that the sensors have long lifetimes in the field, be able to report measurements remotely as well as produce accurate and repeatable data. The development of small or miniature instruments (e.g., micro- or nano-technologies) is encouraged in order to provide small instrument package profiles for use in the field. The technologies that are developed and tested should be innovative and be able to withstand environmental extremes as well as possible disruption due to military activities.

BACKGROUND: SERDP has established a long-term ecosystem management research program at Fort Benning, Georgia, known as SEMP. A major goal of this program is to develop indicators of ecosystem health as well as indicators of ecosystem change. As part of SEMP, the Environmental Characterization and Monitoring Initiative (ECMI) monitors numerous meteorological, soil, and water conditions as well as plant and animal presence. The equipment required to collect these data are often large and expensive and require substantial support in terms of electrical power and maintenance. There is a need to develop innovative sensor technologies that are small and inexpensive while being capable of performing these measurements.

The parameters being monitored as part of ECMI provides a list of possible environmental parameters that could be the focus of this project, but the scope of this effort is not limited to those parameters. This list is available on the SEMP/ECMI website at: http://www.denix.osd.mil/SEMP. The project is not limited to monitoring and evaluating instruments or the monitoring of environmental conditions only at Fort Benning.

SERDP CORE STATEMENT OF NEED FOR FY 2002
POLLUTION PREVENTION – PPSON-02-01

ENVIRONMENTAL FATE AND TRANSPORT OF A NEW ENERGETIC MATERIAL, CL-20

OBJECTIVE: The objective of this statement of need is to determine the transport, fate and environmental effects of the new energetic material known as CL-20. The research should focus on the neat compound and its degradation products in one or more of the following areas:

- transport through the vadose zone and groundwater
- effects of weathering, and biotic and abiotic degradation and transformation
- lethal and sub-lethal environmental effects on:
  - plants
  - soil organisms
  - avian species
  - terrestrial species
  - aquatic species

CL-20 required for this effort will be provided by the government. CL-20 is being considered as a potential replacement for existing propellant and explosive materials. Due to their use, propellants and explosives and their degradation products can be released into the environment. It is essential that the potential impacts of these releases be well known prior to the adoption of CL-20 as a common use energetic material. The work will provide the knowledge necessary to determine these impacts.

BACKGROUND: Hazardous wastes associated with DoD energetic materials life cycles constitute over 40% of DoD's wastes. The costs of managing these wastes have significantly increased the production, maintenance, and disposal costs of the required energetics materials. The fate and effects of energetic materials on training and testing ranges are becoming significant issues that will impact the future use of energetics. As a result, DoD has a responsibility to address pollution by the development of new energetic materials that have equal or superior performance characteristics with less environmental impact.

CL-20, or hexanitrohexaazaisowurtzitane (HNIW), C6H6N12O12, is a high-density cyclic nitramine that is currently being investigated for use as both a high explosive and a propellant. First synthesized in 1987, CL-20 meets insensitive munitions requirements, and has a greater heat of formation and energy output than HMX. Because this material contains no halogens in its composition, combustion produces a minimum signature that is thought to be more environmentally acceptable than propellants made from Ammonium Perchlorate. The environmental impact of the parent compound and potential breakdown products is unknown. CL-20 production is currently at thousands of pounds per year, and quantities will soon be sufficient to permit it to be demonstrated and validated in specific weapons applications. Before this can be done, CL-20's environmental fate, transport and effects must be understood to ensure that it is environmentally benign prior to making implementation or deployment decisions. At this time, very little is known regarding its toxicity or Environmental Fate and Transport (EFT). CL-20 is an odorless, white crystalline solid that is negligibly soluble in water. It is incompatible with strong acids, oxidizers, reducing agents, and alkalies. Upon total decomposition, oxides of carbon and nitrogen are produced. CL-20 is a RCRA hazardous waste. It is expected to be regulated in a manner similar to RDX, HMX and other energetic materials. Neither OSHA nor ACGIH have established exposure limits for CL-20.

SERDP CORE STATEMENT OF NEED FOR FY 2002
POLLUTION PREVENTION – PPSON-02-02

ENVIRONMENTALLY INNOVATIVE TECHNOLOGIES FOR POLYMER MATRIX COMPOSITES REFORMULATION, FABRICATION, AND ASSOCIATED REPAIR PROCESSES

OBJECTIVE: The objective of the proposed work is to develop environmentally benign resins and novel fabrication/repair processes for polymer matrix composites (PMC) while meeting unique component requirements for DoD systems. Specifically, the goals of this research are to:

- Reduce Nitrous Oxides (NOx), volatile organic compounds (VOCs), hazardous air pollutants (HAPs), and ozone depleting substances (ODSs) as by-products of the manufacturing and associated repair cycle, while not producing other byproducts that are harmful to the environment or humans.

- Reduce hazardous solid waste due to short material shelf life and the resulting debris by-products of the manufacturing/repair cycle.

This research will reduce environmental burdens resulting from the processing and repair of composite materials via materials re-formulations, improved processing cycle techniques (from the preparation of pre-impregnated materials through the fabrication of the final, completed composite part ready for assembly) and improved/novel repair procedures. The development of new or alternative resins and/or processing and repair techniques for composite materials will result in significant reductions in the production and/or release of VOCs, NOx, HAPs, ODSs, and hazardous materials and the waste streams associated with these materials.

BACKGROUND: DoD uses composites in applications where they are superior in performance-to-weight and more cost-competitive than other materials. This SON addresses Polymer Matrix Composites (PMCs), also known as reinforced plastic composites. These items are made using reinforcing fibers and a plastic resin matrix. PMC manufacturing has all of the environmental, safety, and health concerns associated with any type of plastics manufacturing, including the use of reactive, toxic, and flammable materials. PMCs are produced by positioning fibers in a specific pattern and adding a liquid resin that polymerizes into a solid plastic. The resulting product is generally bonded to another material and painted or gel-coated to produce the final product. PMC repair can involve both manufacturing and maintenance processes. PMCs that are fully cured are considered non-hazardous solid waste when they are no longer useful. They can be disposed of in a municipal landfill, and some may be recycled.

While cured composite materials are not regulated as hazardous wastes, the manufacture, maintenance, and repair processes associated with composites require sealants, adhesives, bonding agents, resins, pigments, fillers, and fibers that contain and/or involve the use of toxic and hazardous substances (e.g., solvents).

The federal government regulates the use and disposal of these toxic and hazardous substances with environmental and occupational safety and health laws, including the Clean Air Act (CAA), and amendments, the Emergency Planning and Community Right-to-Know Act (EPCRA), and the Resource Conservation and Recovery Act (RCRA). In some cases, state and local governments use these laws as minimum standards for their stricter laws.

SERDP CORE STATEMENT OF NEED FOR FY 2002
POLLUTION PREVENTION – PPSON-02-03

REMOTE LOCATION AND IDENTIFICATION OF EXPENDED MUNITIONS

OBJECTIVE: The objective of the proposed effort is to develop advanced techniques to embed a capability within munitions to allow for the easy and rapid detection and discrimination of fired munitions that failed to detonate or are inert by design. This applies to large projectiles, such as the Mark series bombs (up to 2,000 lbs.), ship-based and land-launched munitions, and to a variety of cluster weapons and their associated submunitions. Specifically, proposed work should address one or more of the following objectives:

- To accurately locate the fired munition in the impact area
- To identify the type of munition (Mark series bomb, howitzer projectile, submunition, spotting charge, etc.)
- To determine the status of individual munitions as to their content (explosive or inert) and, if explosive, the fused condition (fused or unfused)

The proposed technology must not compromise range personnel safety. The proposed technology is expected to reduce the costs of detection, discrimination and removal of UXO. Also required are capabilities to assess buried as well as those munitions lying on the surface, including under/on a variety of terrain (water, desert, forest, mountains, tundra, etc.), and often penetrating a variety of soils, concrete, or armor.

BACKGROUND: UXO consists of a wide variety of projectiles lying on or buried beneath the ground surface. (It is estimated that 70 % of UXO at Fallon Naval Air station in Nevada are buried.) It is critical to quickly locate, identify, and cleanup all expended munitions between exercises. At the Luke AFB, AZ aerial training site (Goldwater Range), over 100,000 large projectiles/bombs are dispensed every year. At the Nellis AFB training range over 4 million pounds of ordnance is dropped per year.

Environmental hazards result not only in danger to personnel, but the hazardous materials in UXO have the long term potential to enter the ecosystem. Munitions left on the range are a potential pollution source as solid waste or leached hazardous material.

An FY 1998 Defense Science Board (DSB) report noted that current UXO characterization efforts lack adequate capability to discriminate currently buried UXO from non-hazardous materials (false alarms) with the result that approximately 75 percent of the costs to remediate a UXO site are currently spent on excavating these false alarms. Therefore, there is a significant need to greatly enhance the detection and discrimination of fired munitions so as to minimize future costly maintenance and cleanup operations.

SERDP CORE STATEMENT OF NEED FOR FY 2002
POLLUTION PREVENTION – PPSON-02-04

LOW TEMPERATURE POWDER COATINGS

OBJECTIVE: The objective of the proposed work is to develop durable, low temperature (less than 230 °F) cured powder coatings or powder coating processes for temperature-sensitive substrates to meet the unique requirements of DoD aircraft/weapon systems. Specifically, this statement of need (SON) seeks to develop coating materials and processes that eliminate or significantly reduce volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) [greater than 95% reduction for both VOCs and HAPs] as applied to temperature-sensitive weapon system components.

The proposed research must address the issue from a systems level and must yield lower environmental life cycle impact than current processes. Depot and field support issues (maintenance and repair) as well as any component/system specific application issues must be considered in the proposed effort. Additionally, powder coating removal, inspection techniques and touchup techniques should be considered. The proposed technology must eliminate or significantly reduce VOCs, HAPs, and hazardous solid or liquid waste streams.

BACKGROUND: Powder coating is the fastest growing industrial finishing method in North America, representing about 15% of the total industrial finishing market. There are about 5,000 powder coating operations applying these coatings for a high-quality and durable finish that resists scratches, corrosion, abrasion and chemicals. The technology has grown substantially since 1980, with total pounds of general thermoset powder sold in North America growing from 20 million to an estimated 385 million in 1999. The process maximizes production, cuts costs, and offers maximum compliance with environmental regulations.

The coatings are used on thousands of parts and products including, but not limited to: store shelving, house appliances, automotive components (including intermediate and clear coats), architectural and building markets, highway projects, electrical products and lighting fixtures, agricultural equipment, home maintenance/patio equipment, athletic equipment, office equipment, and children’s toys. In short, just about any commercial product can be powder coated where the substrate material is not thin or the process does not result in uncontrolled changes in substrate temper that adversely affects the material properties, and its resulting component performance.

Unfortunately, all of the commercial processes involve using relatively high heating ovens (greater than 250 °F) with long heating cycles (greater than 10 minutes) that can cause damage to substrate material properties. These changes may not be a significant problem for commercial applications, but in unique weapon system and aerospace applications, where material properties are often extremely sensitive to high and long heating exposures, the results may be catastrophic to ultimate component performance.

While many types of military equipment components are compatible with the conventional powder coating baking process, there is a large inventory of temperature-sensitive components/systems that require coatings but that cannot tolerate elevated temperatures without incurring substrate damage. Aircraft wheels, radomes, wing leading edges, portable shelters, and thin-skin composites are examples of potential applications.

SERDP CORE STATEMENT OF NEED FOR FY 2002
POLLUTION PREVENTION – PPSON-02-05

SOLID WASTE REDUCTION ASSOCIATED WITH MILITARY RATIONS AND PACKAGING

OBJECTIVE: The objective of the proposed work is to reduce solid waste associated with military rations through the:

- Development of environmentally friendly packaging and/or the evaluation of improved packaging/storage concepts.
- Reduction in the volume of unused military rations discarded based on expired shelf life.
- Improved separation and salvage/reuse of heating elements or new approaches to provide heat for military rations.

This statement of need would significantly reduce the generation of expired ration stock and packaging waste in the field without adversely impacting warfighter acceptance/consumption of rations. Availability of more efficient packaging and the use of more environmentally friendly packaging (e.g., substituting compostable, bio-based packaging materials to reduce landfill volume) will reduce solid wastes in the field. Improved packaging/storage concepts to extend food shelf life or reduced packaging requirements will also yield less solid waste.

BACKGROUND: The DoD must provide food and sustenance to its soldiers, sailors, airmen and marines, throughout the world, under highly variable and often adverse conditions. Meal Ready-to-Eat items (MREs) must have a shelf life of three years at 80 °F or six months at 100 °F. And MREs with expired shelf-lives must be discarded. The presence of the current heating element in the ration unit classifies the MRE waste materials as hazardous waste in some states. Current packaging relies on plastic and metal barrier films that cannot be recycled or disposed of during Naval sea-going operations.

Field surveys show that 1.04 pounds of waste are generated per soldier for each meal served in the field. Of this waste 34% is cardboard, 19% is paper, 17% is metal, and 9.6% plastic (weight percent). Because plastic is the least dense material, it is represents the greatest volume of refuse material. Similar studies have been done on Navy ships where the use and disposal of plastics exacerbates the problem because plastic may not be discharged at sea. Two studies indicated that approximately 3.8 pounds of total food waste per person per day is generated. A breakdown of the waste indicates that 90% of this waste was generated from packaging materials used to protect supplies during storage and shipment. Both the Army and Navy studies show that the reduction of waste by substitution of environmentally improved packaging materials will significantly reduce the burden that food packaging places on the DoD. Consequently, it is desirable for any new proposed MRE materials to be rapidly biodegradable via composting to reduce landfill volume and less injurious to sea mammals. The standard for biodegradation is 45 days reaching 60% mineralization (carbon converted to carbon dioxide).

SERDP CORE STATEMENT OF NEED FOR FY 2002
POLLUTION PREVENTION – PPSON-02-06

ENVIRONMENTALLY ACCEPTABLE PYROTECHNIC FORMULATIONS

OBJECTIVE: The objective of this SON is to develop new formulations for pyrotechnics that are cleaner (i.e., produce non-toxic or smaller waste streams) and more environmentally benign than current formulations. Pyrotechnics can be grouped into six families; decoy flares, illuminating flares, colored flares, smokes (both colored and white), igniters/starters and miscellaneous pyrotechnic items. The focus of this statement of need is to reduce the environmental effects of these devices through substitution of materials in the device to reduce or eliminate toxic or carcinogenic constituents or reaction products. NOTE: Because there are already ongoing projects addressing pyrotechnic igniters/starters, proposals addressing igniters/starters or primers will not be considered.

The proposed effort shall result in fewer inherent environmental risks than the current devices, provide the same or improved level of performance as the current systems, and provide the same or improved level of safety in manufacture and use. The development of environmentally benign pyrotechnics will result in significant reductions in the release hazardous materials during handling and use. Subsequently, this will result in reduced risk to both Service personnel and to the environment exposed to these materials during field operations.

BACKGROUND: Pyrotechnics can be grouped into six families; decoy flares, illuminating flares, colored flares, smokes (both colored and white), igniters/starters and miscellaneous pyrotechnic items. The risk of exposure to the combustion products is considered significant because they are dispersed in air and have potential to be inhaled, ingested or dermally absorbed.

Decoy flares include infrared (IR) and solid pyrophoric flares. The typical IR flare is composed of magnesium, Teflon and Hycar or magnesium, Teflon and Viton. Pyrophoric flares incorporate steel etched by caustics, which presents environment, safety and health hazards. Methods and ingredients for formulation of decoy flares with environmentally acceptable materials are required. Decoy flares are used to lure IR seeking missiles away from their intended targets. Illuminating flares generally contain constituents such as sodium nitrate, barium nitrate, sodium oxalate, magnesium, and binder materials that are considered to be highly toxic, as are the combustion products of barium and sodium.

Colored signaling flares may be various colors and contain barium, strontium, potassium, sodium or other metal salts and a binder. The largest environmental issue related to colored flares is the use of hexachlorobenzene, a known carcinogen and reproductive toxicant. Hexachlorobenzene is also a hazardous air pollutant (HAP) under the Clean Air Act (CAA), a priority pollutant under the Clean Water Act (CWA), regulated under Resource Conservation Recovery Act (RCRA), a Superfund hazardous substance, and is subject to TRI reporting requirements.

Pyrotechnic smokes often contain red phosphorus, hexachloroethane, a variety of organic dyes, zinc oxide, potassium perchlorate, magnesium carbonate, benzanthrone and/or sodium bicarbonate. The organic dyes in the colored smokes are often the hazardous constituents of concern.

SERDP SEED STATEMENT OF NEED FOR FY 2002
POLLUTION PREVENTION – SEEDSON-02-05

ENVIRONMENTALLY BENIGN ANTIFOULING APPROACHES FOR DOD VESSELS

OBJECTIVE: The objective of this program is to develop innovative approaches to reduce/eliminate the use of copper for antifouling protection of DoD ship hulls. The development of environmentally benign antifouling methods will result in the reduction or elimination of large quantities of copper, which currently leach into our waterways or end up on drydock floors.

BACKGROUND: Copper, most often in the form of cuprous oxide, has historically been the major active ingredient of antifouling coating systems. Copper based antifouling coatings have evolved from simple conventional resin/rosin systems (pre-1980's) to ablative mechanisms (1980's) and more recently to self polishing resin systems (1990's). Ablative antifouling paints with cuprous oxide toxicant are on about 95% of the Navy's fleet. Navy hull coating leachate in San Diego Bay alone accounts for 15,827 lbs./year of copper.

Increasingly stringent state, federal and international environmental regulations directed toward biocidal coatings are anticipated. In some harbors, ambient concentrations of copper are at, or very near, the United States Environmental Protection Agency (EPA) mandated water quality criteria (WQC) limits of 3.1 µg/L (ppb) as dissolved copper. In the US, the Uniform National Discharge Standards (UNDS) initiative, a partnership between EPA and the Armed Services to develop one national discharge limit for vessels for all US ports, has identified copper hull leachate as a discharge that may cause negative environmental effects. Therefore, in accordance with UNDS requirements, marine coatings will be subjected to copper release rate limits. In Europe, restrictions on copper are being considered by the UK and the Netherlands, and have been implemented in Sweden.

DoD vessels require a life cycle coating to protect their hulls from attachment of microfouling and macrofouling organisms that increase drag, reduce range and speed, and reduce fuel economy. The Navy spends approximately $500M/year on propulsive fuel, of which $30M-$60M is lost due to increased drag from accumulations of marine fouling on ship hulls as a result of failed or inadequate coating systems. Long-lasting, highly effective anti-fouling coatings are essential to DoD combatants because biofouling impacts mission effectiveness and because intervals between maintenance drydockings for DoD ships are more than double that for commercial vessels. To date, no effective non-biocidal coatings that meet current performance criteria have been identified. The performance criteria are specified in MIL-PERF-24647B.

SERDP SEED STATEMENT OF NEED FOR FY 2002
POLLUTION PREVENTION – SEEDSON-02-06

ENVIRONMENTALLY BENIGN BIOLOGICAL FOULING CONTROL IN HEAT TRANSFER EQUIPMENT

OBJECTIVE: The objective of the proposed work is to develop environmentally benign technologies, methods, and processes to prevent biological fouling in heat exchangers, condensers, water piping systems, locks and dams. Biological fouling of these structures and equipment is a chronic and costly problem for the Navy, Coast Guard and the Army Corps of Engineers.

The proposed work shall address technologies, methods or processes which:

- Are effective in minimizing the effects of microbiological and macrobiological fouling.
- Will satisfy state and federal discharge requirements.
- Will reduce or eliminate requirements for hazardous materials storage.
- Will be economically feasible.

BACKGROUND: Biological fouling is a chronic problem for U.S. Navy and Coast Guard ships (heat exchangers, condensers and seawater piping systems) and for the Army Corps of Engineers (dams, locks, dredges and hydroelectric plants). Biological fouling adversely affects system performance by inhibiting heat transfer and blocking the flow of cooling water.

The primary approach to control biological fouling has been chlorination. However, the discharge of chlorinated water from land-based cooling systems (including dockside chlorinators connected to a ship) is subject to state implemented water quality criteria.

The proposed Uniform National Discharge Standards (UNDS) regulation for chlorine-produced oxidants may further restrict the use of chlorine for biofouling control. The U.S. Navy has established a level of 200 ppb for 2 hours a day as the minimum chlorine level necessary to prevent biological fouling in heat exchangers and condensers. These chlorine levels are well above existing state regulations in Navy ports such as Pearl Harbor and San Diego. Dechlorinators may be used but they are cumbersome, costly and increase hazardous storage requirements. As a result, the continued use of chlorination for biofouling control is in question. Titanium seawater systems on the U.S. Navy's new LPD-17 class ship will not be equipped with chlorinators because of the chlorine discharge issue. New, environmentally benign biological fouling control measures must be adapted.

The costs of ignoring biological fouling, in terms of cost, performance and availability of the ships or other equipment, can be very high. In 1990, the U.S. Navy's submarine force spent over $2.5M cleaning biofouled heat exchangers. A recent report indicated that cleaning biofouled heat exchangers and condensers on a CVN-68 class aircraft carrier cost $25K per unit, or $300K per ship per year.

SERDP SEED STATEMENT OF NEED FOR FY 2002
POLLUTION PREVENTION – SEEDSON-02-07

ENVIRONMENTALLY ACCEPTABLE ALTERNATIVES FOR NONDESTRUCTIVE INSPECTION WITH FLUORESCENT PENETRANT DYES

OBJECTIVE: The objective of this program is to develop alternative inspection techniques to replace nondestructive inspection (NDI) techniques which use fluorescent penetrant (FP) dyes or to develop non-hazardous materials for use in the existing FP dye techniques. These techniques shall be environmentally benign and shall meet or exceed the performance of the current FP dye NDI. Volatile organic compounds (VOCs), hazardous air pollutants (HAPs) and hazardous waste streams shall be minimal.

Availability of an environmentally benign NDI technique capable of rapidly detecting cracks and defects in DoD weapons system or aerospace components. Performance shall meet or exceed that of currently used fluorescent penetrant dye NDI techniques. The NDI techniques will have reduced toxic release inventory emissions and minimal or no hazardous waste stream.

BACKGROUND: The manufacture and subsequent in-service evaluation of metal parts used in military applications require inspection to ensure that there are no critical defects. The most widely practiced inspection technique is a fluorescent penetrant dye (FPD) nondestructive test. The test is accomplished by covering the part with penetrating oil containing fluorescent dye. The excess oil on the surface of the part is removed by rinsing or dipping the part in chemicals designed to remove the excess oil. The part is then treated with a chemical developer. If surface defects exist, the fluorescent dye remaining in the defect can be seen under near-ultraviolet or black light. Highly trained and certified inspectors perform these tests. Field and flight line inspections are performed using portable inspection kits consisting of aerosol spray cans of dye, rinse and developer. Solvents used in the process have volatile components and the process generates oily waste rags. NAVAIR has a FP waste stream of 1,300,000 pounds annually with a disposal cost of $650K. Army estimates disposal costs of $400K per year and the Air Force estimates $3M per year. Handling and disposal of the wastes associated with these processes cost the DoD $4 M per year.

APPENDIX F
List of Acronyms

3D	Three-Dimensional
AAP	Army Ammunition Plant
AAR	Annular After Reactor
AB	After Burner
A/C	Aircraft
ACA	Air Compliance Advisor
ADN	Ammonium Dinitramide
ADPA	American Defense Preparedness Association
AEC	Army Environmental Center
AEMSS	Advanced Enclosed Mast/Sensor System
AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
AFCESA	Air Force Civil Engineering Support Activity
AFM	Atomic Force Microscopy
AFOSR	Air Force Office of Scientific Research
AFRL	Air Force Research Laboratory
AFRL/EQ	Air Force Research Laboratory/Environmental Quality
AFRL/MLQ	Air Force Research Laboratory/Materials Laboratory
AH	Attack Helicopter
AHPC	Army High-Performance Computing
AIChE	American Institute of Chemical Engineers
AICUZ	Air-Installation Compatible Use Zone
Al	Aluminum
ALC	Air Logistics Center
AMS	Aerospace Materials Specifications
AMT	Applied Membrane Technology, Inc.
ANL	Argonne National Laboratory
ANM	Animal Noise Monitor
ANSI	American National Standards Institute
AOP	Advanced Oxidation Process
AP	Ammonium Perchlorate
AQMD	Air Quality Management Districts
AQUASIM	Computer Program for the Identification and Simulation of Aquatic Systems
AR	After Reactor
ARA	Applied Research Associates
ARC	ARCInfo, GIS System
ARDEC	(U.S. Army) Armaments Research, Development & Engineering Center
AREP	Alternative Refrigerant Evaluation Program
ARL	Army Research Laboratory
ARM	Atmospheric Radiation Measurement
ARPA	Advanced Research Projects Agency
ARS	Agriculture Research Service
As	Arsenic
ASAN	Assessment System for Aircraft Noise
ASPA	Advanced Solid Propellant Armament

ASTE	Advanced Strategic and Tactical Expendables
ASTM	American Society for Testing and Materials
ATD	Advanced Technology Demonstration
ATEDS	Advanced Technology Expendables and Dispenser System
ATLAS	Advanced Testing Line for Actinide Separations
ATOFMS	Aerosol Time of Flight Mass Spectrometer
ATR	Automated Target Recognition
ATR-FTIR	Attenuated Total Reflectance Fourier Transform Infrared Spectrometry
ATRP	Automatic Target Recognition Processor
ATTACC	Army Training and Testing Area Carrying Capacity
BAA	Broad Agency Announcement
BAAP	Badger Army Ammunition Plant
BACT	Best Available Control Technology
BBR	Badlands Bombing Range
BDC	Background Data Center
BDK	Batch Design Kit
BLM	Bureau of Land Management
BMP	Best Management Practice
BOD	Biological Oxygen Demand
BRAC	Base Realignment and Closure
BSAA	Boric-Sulfuric Acid Anodizing
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
BTU	British Thermal Unit
CA	Coupling Agent
CAA	Chromic Acid Anodizing
CAA	Clean Air Act
CAAA	Clean Air Act Amendments
CAH	Chlorinated Aliphatic Hydrocarbon
CAME	Clean Agile Manufacturing of Energetics
CAMIS	Computerized Airborne Multicamera Imaging System
CARB	California Air Resources Board
CARC	Chemical Agent Resistant Coating
CATS	Controlled Archeological Test Site
CAV	Composite Armored Vehicle
CBC	Construction Battalion Center
CCAC	Close Combat Armament Center
CCAD	Corpus Christi Army Depot
CCC	Chromate Conversion Coatings
CCD	Charge Coupled Devices
CCRT	Center for Conservation Research & Technology
Cd	Cadmium
cDCE	cic-1,2-dichloroethene
CDF	Confined Disposal Facility
CE	Civil Engineering
CEMS	Continuous Emissions Monitoring System
CER	Center for Environmental Research
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (called Superfund)
CERL	(USACE, ERDC) Construction Engineering Research Laboratory

CFC	Chlorofluorocarbon
CFD	Computational Fluid Dynamics
CHILD	Channel-Hillslope Integrated Landscape Development
CHPPM	Center for Health Promotion and Preventive Medicine
CHSSI	Common High-Performance Scalable Software Initiative
CL-20	Hexanthrohexaazaisowurtzitane
CLEO	Conference on Lasers and Electro- Optics
CLNAWS	China Lake Naval Air Weapons Station
ClOx	Chlorine Oxide
ClRB	Perchlorate-Reducing Bacteria
CMS	Cylindrical Magnetron Sputtering
CNO	Chief of Naval Operations
CO	Carbon Monoxide
CODEHOP	Consensus- Degenerate Hybrid Oligonucleotide Primers
COPC	Chemicals of Potential Concern
COTS	Commercial-off-the-Shelf
CP	Compliance (SERDP Thrust Area)
CPAT	Corrosion Prevention Advisory Teams
CPC	Corrosion Prevention Compound
CPT	Cone Penetrometer
Cr	Chromium/Chromates
CRADA	Cooperative Research and Development Agreement
CRREL	(USACE, ERDC) Cold Regions Research and Engineering Laboratory
CRS	Corona Radical Shower
CS	Conservation (SERDP Thrust Area)
CT	Carbon Tetrachloride
CT	Computed Tomography
CTC	Control Technology Center
CTIO	Coatings Technology Integration Office
Cu	Copper
CU	Cleanup (SERDP Thrust Area)
CW	Continuous Wave
CWA	Clean Water Act
CZARA	Coastal Zone Act Reauthorization Amendment
DAF	DNA Amplification Fingerprint
DALM	Diazoluminomelanin
DARPA	Defense Advanced Research Projects Agency
DC	Direct Current
DCA	Dichloroacetic Acid
DCA	Dichloroethane
DCAA	Dynamic Contact Angle Analyzer
DCE	Dichloroethylene
DDR&E	Director, Defense Research and Engineering
DECIM	Defense Environmental Corporate Information Management
DEM/VAL	Demonstration/Validation
DENREC	Delaware Department of Natural Resources and Environmental Control
DERA	Defense Environmental Restoration Account
DESCIM	Defense Environmental Security Corporate Information Management
DETRS	DoD Environmental Technology Requirements Strategy
DFA	Difluoroamino

DFSP	Defense Fuel Supply Point
DFSS	Dedicated Feedstock Supply Systems
DGGE	Denaturing Gradient Gel Electrophoresis
DHR	Directional Hemispherical Reflectance
DLA	Defense Logistics Agency
DMA	Differential Mobility Analyzers
DMG	Desert Managers Group
DMMF	Developmental Manufacturing and Modification Facility
DMMP	Dimethylmethylphosphonate
DNA	Defense Nuclear Agency
DNA	Deoxyribonucleic Acid
DNAPL	Dense Non-Aqueous Phase Liquid
DNB	Dinitrobenzene
DNL	Dry Low NOx
DNT	Dinitrotoluene
DNTS	Dover National Test Site
DOC	Dissolved Organic Carbon
DoD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOM	Dioctyl Maleate
DPG	Dugway Proving Ground
DRE	Destruction and Removal Efficiency
DTPA	Diethylenetriaminepentaacetic Acid
DUECC	Defense Utility Energy Coordinating Council
DUSD(ES)	Deputy Under Secretary of Defense for Environmental Security
EA	Environmental Assessment
EAE	Environmentally Acceptable Endpoint
EAM	Effective Area Model
ECIP	Energy Conservation Investment Program
ECMI	Ecosystem Characterization and Monitoring Initiative
ECO-SSL	Ecological Soil Screening Levels
ECP	Engineering Change Proposal
ECU	Environmental Control Unit
EDYS	Ecological Dynamics Simulation
EFT	Environmental Fate and Transport
EIS	Electrochemical Impedance Spectroscopy
EIS	Environmental Impact Statement
EM	Electromagnetic
EM	Environmental Management
EMAA	Encapsulated Micron Aerosol Agents
EMAP	Environmental Monitoring and Assessment Program
EMI	Electromagnetic Induction
EO	Electro-Optic
EO	Executive Order
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
EPRI	Electric Power Research Institute
EQT	Environmental Quality Technology Program
ERA	Ecological Risk Assessment

ERAP	Environmental Risk Assessment Program
ERDC	(USACE) Engineer Research and Development Center
ERDEC	(U.S. Army) Edgewood Research, Development and Engineering Center
ERPM	Emission Reduction Planning Model
ESA	Endangered Species Act
ESD	Electro-Spark Deposition
ESII	Enviroenergy Systems International, Inc.
ESMB	Explosive Standoff Minefield Breecher
ESTCP	Environmental Security Technology Certification Program
ETH	Ethene
EXCEL	Experimental Chloride Extraction Line
FAA	Federal Aviation Administration
FBR	Fluidized Bed Reactor
FDEM	Frequency Domain Electromagnetic
Fe	Iron
FEDS	Federal Energy Decision Screening
FEMP	Federal Energy Management Program
FFCA	Federal Facilities Compliance Act
FFP	Full-Flow Processor
FIBRC	Federal Integrated Biotreatment Research Consortium
FIC	Fluoroiodocarbon
FID	Free-Induction Decay
FORS	Fiber Optic Raman Sensor
FOX	Fluoroalkoxymethyl-3methyl-Oxetane
FP	Fluorescent Penetrant
FPD	Freezing Point Depressant
FTS	Fourier Transform Spectrometer
FUDS	Formerly Used Defense Sites
FWPPCA	Federal Water Pollution Prevention and Control Act
GAC	Granular Activated Carbon
GC	Gas Chromatography
GCDIS	Global Change Distributed Information System
GC/FID	Gas Chromatography/Free Induction Decay
GC/MS	Gas Chromatography/Mass Spectrometry
GCMS	Gas Chromatography Coupled Mass Spectroscopy
GE	General Electric
GEM	Navy Green Energetics Manufacturing Program
GEM	Genetically Engineered Microorganisms
GIS	Geographic Information System
GMS	Groundwater Modeling System
GO	Genetic Optimization
GOCO	Government-Owned/Contractor-Operated
GOES	Geostationary Operational Environmental Satellites
GPR	Ground-Penetrating Radar
GPS	Global Positioning System
GRASS-PRISM	Geographic Resource Analysis Support System - Planning and Resource Integration Stewardship Model
GRFL	Groundwater Remediation Field Laboratory
GSE	Ground Support Equipment

GUI	Graphical User Interface
GV	Grassland Value Function
GWP	Global Warming Potential
H_2	Hydrogen
HAP	Hazardous Air Pollutant
HAZMAT	Hazardous Materials
HAZMIN	Hazardous Waste Minimization
HBNQ	High-Bulk-Density Nitroguanidine
HC	Hydrocarbon
HCAT	Hard Chrome Alternatives Team
HCFC	Hydrochlorofluorocarbon
HF	Hydrogen Fluoride
HFBA	Hierarchical Foreground Background Analysis
HFC	Hydrofluorocarbon
HMT	High Mesa Technologies
HMX	Octahydro-1,3,5,7-Tetranitro 1,3,5,7-Tetrazocine
HOPS	Heuristic Optimized Processing Systems
HPLC	High Performance Liquid Chromatography
HRV	Historic Range in Variation
HSI	Hyperspectral Imaging
HSRC	Hazardous Substance Research Center
HUD	Department of Housing and Urban Development
HVLP	High Volume Low Pressure
HVOF	High-Velocity Oxygen Fuel
HVTS	High Velocity Thermal Spray
HW	Hazardous Wastes
HWRC	Hazardous Waste Research Center
IAAP	Iowa Army Ammunition Plant
IBEAM	Installation Baseline Energy Analysis Model
ICA	Incremental Cost Analysis
ICAO	International Civil Aviation Organization
ICUZ	Installation Compatible Use Zone
ID	Internal Diameter
IDIF	Integrated Diffuser Injector Flameholder
IDLAMS	Integrated Dynamic Landscape Analysis and Modeling System
IHPTET	Integrated High Performance Turbine Engine Technology
IMC	Intermetallic Compound
INEL	Idaho National Engineering Laboratory
InGaAs	Indium Gallium Arsenide
InSb	Indium Antimony
INT	Iodonitrotetrazolium Chloride
IPD	Integrated Product Development
IPM	Integrated Pest Management
IPPD	Integrated Product/Process Development
IPR	In-Progress Review
IPSC	Interagency Perchlorate Steering Committee
IPT	Integrated Product Team
IR	Infrared
IRIS	Integrated Risk Information System

IRP	Installation Restoration Program
ISCO	In Situ Chemical Oxidation
ISCT	In-Situ Chemical Treatment
ITAM	Integrated Training Area Management
IUSS	Integrated Undersea Surveillance System
IVD	Ion Vapor Deposition
IWTP	Industrial Waste Treatment Plants
JASPPA	Joint Acquisition and Sustainment Pollution Prevention Activity
JDEP	Joint Depot Environmental Panel
JEMP	Joint Engineers Management Panel
JETC	Jet Engine Test Cell
JG-PP	Joint Group on Pollution Prevention
JP-8	Type 8 Jet Fuel
JPG	Jefferson Proving Ground
KBB	Karner Blue Butterfly
LAAP	Louisiana Army Ammunition Plant
LAMS	Laser Ablation Mass Spectroscopy
LANDSAT	Land Remote-Sensing Satellite
LANL	Los Alamos National Laboratory
LBCC	Land Based Carrying Capacity
LC	Laboratory Combustor
LCA	Life Cycle Assessment
LCAAP	Lake City Army Ammunition Plant
LCAD	Life Cycle Assessment and Design
LCED	Life Cycle Engineering and Design
LCI	Life Cycle Inventory
LCO_2	Liquid CO_2
LCTA	Land Condition Trend Analysis
LHM	Lead-Based Paint Hazard Management System
LIBS	Laser-Induced Breakdown Spectroscopy
LIF	Laser-Induced Fluorescence
LIN	Liquid Nitrogen
LIS	Laser Ignition System
LLNL	Lawrence Livermore National Laboratory
LMS	Land Management System
LNAPL	Light Non-Aqueous Phase Liquid
LO	Low Observable
LOVA	Low Vulnerability Ammunition
LRS&T	Long Range Science and Technology Program
LTM	Long-Term Monitoring
LTTU	Long-Term Test Apparatus
M&S	Modeling and Simulation
MACT	Maximum Achievable Technology Control
MADOM	Magnetic and Acoustic Detection of Mines
MAJCOM	Major Commands
MALDI	Matrix Assisted Laser Desorption Ionization
MARPOL	International Maritime Organizations Marine Pollution Convention

MARS	Mobile Analytical Reconnaissance System
MAS	Millimeter-Wave Atmospheric Sounder
MB/MS	Molecular Beam/Mass Spectrometric
MBT	Membrane BioTreatment
MCAGCC	Marine Corps Air-Ground Combat Center
MCB	Marine Corps Base
MCFC	Molten Carbonate
MCRA	Material/Chemical Risk Assessment
MeCl	Methylene Chloride
MEK	Methyl Ethyl Ketone
MF-EMI	Medium Frequency Electromagnetic Induction
MFR	Monthly Financial Reporting
MIBK	Methyl Isobutyl Ketone
MIC	Metastable Intermolecular Composites
MIDAS	Munitions Items Disposal Action System
MIPR	Military Interagency Purchase Request
MIT	Massachusetts Institute of Technology
MLFMA	Multi-Level Fast-Multipole Algorithm
MM	Modifier Molecules
MMATS	Marine Mammal Acoustic Tracking System
MMMS	Mobile Meteorological Measurement System
MMPA	Marine Mammals Protection Act
MMRP	Marine Mammal Research Program
Mn	Manganese
MOA	Memorandum of Agreement
MODIS	Moderate-Resolution Imaging Spectroradiometer
MOI	Multiorifice Impactors
MoM	Method of Moment
MOSFET	Metal-Oxide Semiconductor Field-Effect Transistor
MOU	Memorandum of Understanding
MPC	Mobile Power Center
MPN	Most Probable Number
MRE	Meal Ready-to-Eat
MRI	Magnetic Resonance Imaging
MR/H	Mine Reconnaissance/Hunter
mRNA	Messenger Ribonucleic Acid
MRTFB	Major Range and Test Facility Base
MSAT	Mobile Source Air Toxics
MSS	Multispectral Scanner
MT3D	Modular Transport in 3D
MTADS	Multi-Sensor Towed Array Detector System
MTBE	Methyl Tertiary Butyl Ether
MTR	Military Training Routes
MTV	Magnesium-Teflon-Viton
MUC	Military-Unique Contaminants
MUDSS	Mobile Underwater Debris Survey System
MWCO	Molecular Weight Cutoff
MWO	Modification Work Order
N_2	Nitrogen
NA	Natural Attenuation

NAAQS	National Ambient Air Quality Standard
NAC	Nitro Aromatic Compound
NADEP	Naval Aviation Depot
NADPH	Reduced Nicotinamide Adenine Dinucleotide Phosphate
NAGPRA	Native American Grave Protection and Repatriation Act
NAPL	Non-Aqueous Phase Liquid
NAS	Naval Air Station
NASA	National Aeronautics and Space Administration
NATA	National Air Toxics Assessment
NATO	North Atlantic Treaty Organization
NATS	Natural Attenuation Test Simulator
NAVSEA	Naval Sea Systems Command
NAX	Natural Attenuation of Explosives
NBS	National Biological Survey
NC	Nitrocellulose
NCBC	Navy Construction Battalion Center
NCIBRD	National Center for Integrated Bioremediation Research and Development
NCMS	National Center for Manufacturing Sciences
NDCEE	National Defense Center for Environmental Excellence
NDE	Nondestruction Evaluation
NDFT	Non-Local Density Functional Theory
NDI	Nondestructive Inspection
NDI	Non-Developmental Item
NED	National Environmental Database
NEETC	National Environmental Education and Training Center
NEPA	National Environmental Policy Act
NERL	National Exposure Research Laboratory
NESHAP	National Emissions Standards for Hazardous Air Pollution
NETTS	National Environmental Technology Test Site
NFESC	Naval Facilities Engineering Services Center
NG	Nitroguanidine
NGB	National Guard Bureau
NCERQA	National Center for Environmental Research and Quality Assurance
NCSA	National Center for Super Computers
NGP	Next Generation Fire Suppression Technology Program
NHPA	National Historic Preservation Act
Ni	Nickel
NIST	National Institute of Standards and Technology
NLCR	Nonlinear Continuum Regression
NLOS	Non Line-of-Sight
NMERI	New Mexico Engineering Research Institute
NMP	N-Methyl-Pyrolidone
NMR	Nuclear Magnetic Resonance
NN	Neural Network
NOAA	National Oceanic and Atmospheric Administration
NOP	Nebraska Ordnance Plant
NOV	Notice of Violation
NOx	Nitrogen Oxide
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NQ	Nitroguanidine

NRC	National Research Council
NRCS	National Resource Conservation Service
NRHP	National Register of Historic Places
NRL	Naval Research Laboratory
NRMRL	National Risk Management Research Laboratory
NSPS	New Source Performance Standards
NSWC	Naval Surface Warfare Center
NSWC-IHD	Naval Surface Warfare Center - Indian Head Division
NTIS	National Technical Information Service
NTL	National Test Location
NTP	Non-Thermal Plasma
NUFT3D	Non-Isothermal Unsaturated/Saturated F&T in 3D
O&M	Operation and Maintenance
OB/OD	Open Burning/Open Detonation
OC-ALC	Oklahoma City Air Logistics Center
ODC	Ozone Depleting Chemicals
ODP	Ozone Depleting Potential
ODS	Ozone Depleting Substances
ODUSD(ES)	Office of the Deputy Under Secretary of Defense for Environmental Security
OEM	Original Equipment Manufacturer
OEW	Ordnance Explosive Wastes
ONI	Office of Naval Intelligence
ONR	Office of Naval Research
OO-IDLAMS	Object-Oriented Integrated Dynamic Landscape Analysis and Modeling System
OPC	Optical Particle Counters
OPNAV	Naval Operations, Headquarters Staff (Pentagon)
OPNAVINST	Naval Operations Instruction
ORD	Office of Research and Development
ORNL	Oak Ridge National Laboratory
OS3D	Operator Splitting in 3D
OSHA	Occupational Safety and Health Administration
OSU	Ohio State University
OTD	Office of Technology Development
OWS	Oil/Water Separators
PAA	Phosphoric Acid Anodize
PAFC	Phosphoric Acid Fuel Cells
PAH	Polycyclic Aromatic Hydrocarbon
PAS	Photoelectric Aerosol Sampler
PAS	Polyalkyl Sulfone
Pb	Lead
PBG	Propellant Burning Ground
PBR	President's Budget Request
PBPK	Physiologically-Based Pharmacokinetic
PCA	Tetrachloroethane
PCB	Polychlorinated Biphenyls
PCE	Perchloroethylene (tetrachloroethylene)
PCR	Polymerase Chain Reaction
PDD	Perfluoro Dimethyl Dioxol
PDD-TFE	Perfluoro Dimethyl Dioxol Copolymer with Tetrafluoro Ethylene

PDM	Programmed Depot Maintenance
PED	Photoacoustic Elemental Device
PED	Photoelectric Detector
PE-ECD	Photoemissive Electron Capture Detector
PE-IMS	Photoemissive Ion Mobility Spectrometer
PEO	Program Executive Officer
PEO/FAS	Program Executive Officer for Field Artillery Systems
PEP	Propellants, Explosives, Pyrotechnics
PG	Propylene Glycol
PI	Principal Investigator
PID	Photoionization Detector
PLIBS	Portable Laser-Induced Breakdown Spectroscopy
PM	Particulate Matter
PM	Program Manager
PMB	Plastic Media Blasting
PMC	Polymer-Matrix Composite
PNL	Pacific Northwest Laboratory
PNN	Probabilistic Neural Network
PNW	Pacific Northwest
POAM	Polar Ozone and Aerosol Monitor
POL	Petroleum, Oil, Lubricants
POSS	Poly(oligosilsesquioxane)
PP	Pollution Prevention (SERDP Thrust Area)
ppb	Parts per Billion
PPLN	Periodically-Poled, Lithium Niobate
PRB	Permeable Reactive Barrier
PTFE	Polytetrafluoroethylene
PTT	Platform Transmitter Terminals
PVD	Physical Vapor Deposition
QA/QC	Quality Assurance/Quality Control
QMP	Quality Management Plan
QSAR	Quantitative Structural Activation Reaction
R&D	Research and Development
RABITT	Reductive Anaerobic Biological In-Situ Treatment Technology
RACER	Remedial Action Cost Engineering and Requirements
RAIDS	Remote Atmospheric and Ionospheric Detection System
RAM	Radar Absorbing Materials
RASS	Radio Acoustic Sounding System
RBCA	Risk-Based Corrective Action
RCI	Rapid Commercialization Initiative
RCRA	Resource Conservation and Recovery Act
RCW	Red-Cockaded Woodpecker
RDBMS	Relational Database Management System
RDT&E	Research, Development Test & Evaluation
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine
REEP	Renewable and Energy Efficiency Planning
RfD	Reference Dose
RFMSS	Range Facilities Management Support System
RMA	Rocky Mountain Arsenal

RMS	Root Mean Square
RNA	Ribonucleic Acid
ROD	Record of Decision
RQL	Rich- Burn, Quick-Quench, Lean-Burn
RREL-EPA	Risk Reduction Engineering Laboratory - Environmental Protection Agency
RT-PCR	Reverse Transcriptase-Polymerase Chain Reaction
RTDF	Remediation Technologies Development Forum
RTG	Room Temperature Gradiometer
RTV	Room Temperature Vulcanizing
RUSLE	Revised Universal Soil Loss Equation
S&T	Science and Technology
S-O&CS	Smokes, Obscurants & Chemical Simulant Agents
SAB	Scientific Advisory Board
SAE	Society of Automotive Engineers
SAGE	Solvent Alternatives Guide
SALSA	Semi-Arid Land Surface Atmosphere
SANS	Small Angle Neutron Scattering
SAPT	Symmetry Adapted Perturbation Theory
SAR	Structural Activity Relationships
SAR	Synthetic Aperture Radar
SASW	Spectral Analysis of Surface Wave
SAVI	Soil-Adjusted Vegetation Index
SBAA	Sulfuric-Boric Acid Anodize
SBIR	Small Business Innovation Research
SBR	Sequential Batch Reactors
SCAMP	Subsurface Cleanup and Mobilization Processes
SCAPS	Site Characterization and Analysis Penetrometer System
SCF	Supercritical Fluid
SCFE	Supercritical Fluid Extraction
SCR	Selective Catalytic Reduction
SCM	Source Characterization Model
SCWO	Supercritical Water Oxidation
SEAM3D	Sequential Electron Acceptor Model in 3D
SEED	**SE**RDP **E**xploratory **D**evelopment
SEM	Scanning Electron Microscope
SEMP	SERDP Ecosystem Management Program
SERB	Solvent Extraction Residual Bioremediation
SERDP	Strategic Environmental Research and Development Program
SERS	Surface Enhanced Raman Sensor
SF	Supercritical Fluid
SFC	Specific Fuel Consumption
SFE	Supercritical Fluid Extraction
SHDS	Solvent Handbook Data System
SHS	Self-Propagating, High-Temperature Synthesis
SiC	Silicon Carbide
SIFDT	Selected Ion Flow-Drift Tube
SIMWE	Simulated Water Erosion
SKP	Scanning Kelvin Probe
SLPM	Standard Liters Per Minute
SMCA	Single Manager for Conventional Ammunition

SMPS	Scanning Mobility Particle Sizer
Sn	Tin
SNAP	Significant New Alternatives Policy
SNL	Sandia National Laboratory
SNRM	Strategic Natural Resources Management
SO_2	Sulfur Dioxide
SODS	Seismic Ordnance Detection System
SON	Statement Of Need
SOP	Standard Operating Procedure
SOx	Sulfur Oxide
SPME	Solid-Phase Microextraction
SRS	Savannah River Site
SRTC	Savannah River Technology Center
SRTZ	Sequence of Reactive Treatment Zones
STR	Synthetic Tandem Repeat
SVE	Soil Vapor Extraction
SWB	Site Water Balance
TAC	Technical Advisory Committee
TACOM	(U.S. Army) Tank-Automotive & Armaments Command
TAMU	Texas A&M University
TAP	Technical Advisory Panel
TARA	(DoD Environmental) Technology Area Review & Assessment
TCA	Trichloroacetic Acid
TCA	Trichloroethane
TCE	Trichloroethylene
TCLP	Toxicity Characteristic Leachate Procedure
TD	Total Dissolved
TDL	Tunable Diode Laser
TDP	Technology Development Plan
TDS	Total Dissolved Solids
TEC	(USACE, ERDC) Topographic Engineering Center
TEM	Technology Exchange Meeting
TES	Threatened and Endangered Species
TES	Threatened, Endangered, and Sensitive
TET	Tetryl
TETAT	Technology Education and Training Advisory Taskforce
Tg	Transition Temperature
TIPPP	Tidewater Interagency Pollution Prevention Program
TIR	Thermal Infrared
TIWET	The Institute for Wildlife and Environmental Toxicology
TL	Transmission Loss
TM	Landsat Thematic Mapper
TLM	Test Location Manager
TMDL	Total Maximum Daily Limit
TMS	Thematic Mapper Simulator
TNAZ	Tri-Nitro Azetidine
TNB	Trinitrobenzene
TNT	Trinitrotoluene
TOF-SIMS	Time of Flight Secondary Ion Mass Spectrometry
TPE	Thermoplastic Elastomer

TRI	Toxic Release Inventory
TRU	Transuranic Radioactive Waste
TSVP	Thermal Spray Vitrification Process
TTAWG	Technology Thrust Area Working Group
TTU	Texas Technological University
TVC	Trapped Vortex Combustor
UAT	Urban Air Toxic
UATS	Urban Air Toxics Strategy
UB	Ultra Broadband
UC	University of California
UFA	Unsaturated Flow Apparatus
UFAL	Ultra-Fine Aluminum
UHC	Unburned Hydrocarbons
UM	University of Minnesota
UNDEERC	University of North Dakota Energy and Environmental Research Center
UNDS	Uniform National Discharge Standards
UNR	University of Nevada-Reno
USACE	United States Army Corps of Engineers
USAF	U.S. Air Force
USDA	United States Department of Agriculture
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USPED	Unit Stream Power Erosion/Deposition
UST	Underground Storage Tank
USU	Utah State University
UTARNG	Utah Army National Guard
UTM	The University of Texas Chemical Food Simulator
UVRS	Ultraviolet Remote Sensing
UWB	Ultra Wide Band
UXO	Unexploded Ordnance
VARTM	Vacuum-Assisted Resin Transfer Molding
VC	Vinyl Chloride
VCC	Vortex Containment Combustion
VCPI	Visual Cleaning Performance Indicator
VHF	Very High Frequency
VNIR	Visible/Near Infrared
VNTR	Variable Number of Tandem Repeats
VOC	Volatile Organic Compound
VPISU	Virginia Polytechnic Institute and State University
WASI	Wide-Area Spectral Imaging
WEPP	Water Erosion Prediction Project
WEPS	Wind Erosion Prediction System
WHV	Wildlife Habitat Value Function
WIC	Water-Injection Controller
WPAFB	Wright Patterson Air Force Base
WR	Water Reducible
WS	Weapon Systems

WWW	World Wide Web
XAS	X-ray Absorption Spectroscopy
XCRIS	X-windows-based Cultural Resource Information System
XPS	X-ray Photo-Electron Spectroscopy
XRD	X-ray Diffraction
XRF	X-ray Fluorescence
XRS	X-ray Spectrometry
XSD	Halogen Specific Detector
YPG	Yuma Proving Ground
Zn	Zinc

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